# ANALYSIS OF URBAN STORM-WATER QUALITY DATA FROM TWO BASINS IN COLUMBUS, OHIO

A Senior Thesis

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by

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## ABSTRACT

To assess urban storm water quality characteristics in the metropolitan area of Columbus, Ohio, two drainage basins were equipped with automatic water quality samplers, monitors, rain gages, and stream gages. Over a two year period samples from the two basins were analyzed for 46 chemical quality parameters. The analysis of the data followed three approaches. First the constituent concentrations were analyzed and compared with Ohio EPA warm-water habitat standards. The results of this showed high levels of copper, iron, lead, and zinc. The second approach was bivariate correlations and regression analysis. This approach yielded information about relationships between constituents but had few uses. The third approach was the use of multiple regression analysis to relate storm yields to rainfall characteristics. In general, the results indicated that the storm yields are dependent on antecedent conditions of the storm.

# INTRODUCTION

## Background

Urban stormwater runoff has always been underestimated as a source of streamwater pollution. One of the reasons for this is the ever increasing need for domestic and industrial sewage treatment facilities in our national effort to clean up our rivers and streams (Ellis, 1976, p. 730). The Virginia State Water Control Board, in 1971, developed the "Occoquan Policy" to replace 11 secondary wastewater treatment plants with a advanced regional wastewater treatment plant (ATW) in order to slow or stop the eutrophication of the Occoquan Reservoir. A study by Grizzard et al. (1976) showed that the ATW would not be as effective as planned in reducing pollution loads in the Occoquan Watershed. The reason for this was the untreated urban stormwater runoff was also a major source of pollution in the watershed. Many other studies have recognized that urban stormwater runoff is a major source of pollution for the nation's waterways (Griffin, 1978, p. 1-6; Helsel, 1978, p. 1-11; Miller and McKenzie, 1978, p. 1-2).

In order to better understand this source of pollution, the mechanics of urban runoff must be understood. As water falls to earth as rain it absorbs dust, ash, smoke, and gases found in the air. These contaminates are produced by the concentration of vehicular traffic and industries in an urban environment (Helsel, 1978, p. 19-23). As the rain hits the ground some of it infiltrates into the soil carrying it's contaminates into the soil and some of it evaporates back into the atmosphere leaving behind the contaminates. The rainfall that doesn't infiltrate or evaporate is excess precipitation and flows over the ground, rooftops, streets, driveways and parking lots absorbing more contaminates as it goes. It assimilates oils, detergents, metals, nutrients, organics, and other chemicals as it flows over litter, garbage, concrete, asphalt, metallic debris, and other debris associated with an urban environment. It picks up the dust and dirt from by-products of combustion and vechicular wear (Ellis, 1976, p. 730). This runoff then enters rivers and streams by overland flow or storm sewers, adding to a normal load of constituents from groundwater flow and erosion of the streambank by the higher flows associated with storm events. It is evident then the chemical loading of an urban stream is effected by the amount of air pollution, the amount of dust and dirt, and the amount of debris in and around the watershed.

In a study by Helsel (1978, p. 19-21) it was reported that the sources for lead, copper, cromium, and zinc were many products associated with automobile traffic, such as gasoline, motor oil, transmission fluid, antifreeze, brake fluids, brake linings, tires, and materials used in the vehicles themselves These sources would be found on or near highways and parking lots because of "wear and tear" on the vehicles. Other pollutants such as cadmium, iron, and zinc can come from industrial sources and nutrients and organics can come from residential areas as washoff from yard up-keep operations.

In the last few years many studies in urban runoff quality have been made and the results of these studies have been varied (Miller and McKenzie, 1978, p. 1-2). These studies have shown the need for collection of site-specific data because of widely varying local and regional conditions (Pitt and Field, 1977, p. 432) and the need for standardization of study methods to better understand the cause-and-effect relationships for urban stormwater runoff (Bradford,1977,p. 621)

## Objective

This study has two main objectives, the first is the modification of the U.S.G.S. Urban Hydrology Monitor and Sampler to use on small urban drainage basins and the development of methods to best utilize this equipment. The second objective is to obtain site-specific data for two urban basins and use this information to better understand the interrelationships of the constituents concentrations and antecedent and storm conditions.

## Analytical Approach

The analytical approaches used in this study are similar to the ones used in Miller and McKenzie (1978, p. 2). First, constituent concentrations were analyzed and compared with Ohio EPA water quality standards. The second approach was the use of correlations and bivariate regressions of constituents to better understand interrelationships. The third approach was the use of multiple-linear regression analysis to identify important independent parameters affecting constituent concentrations.

# BASIN LOCATIONS, DESCRIPTIONS, AND CHARACTERISTICS

## Basin locations

The locations of the two streamflow and sampling stations and the rain gages are shown in figure 1, and are described below. The streamflow and sampling stations are identified by an eight-digit station number and the rainfall stations, if a different location than the streamflow stations, are identified by a fifteen-digit station number.

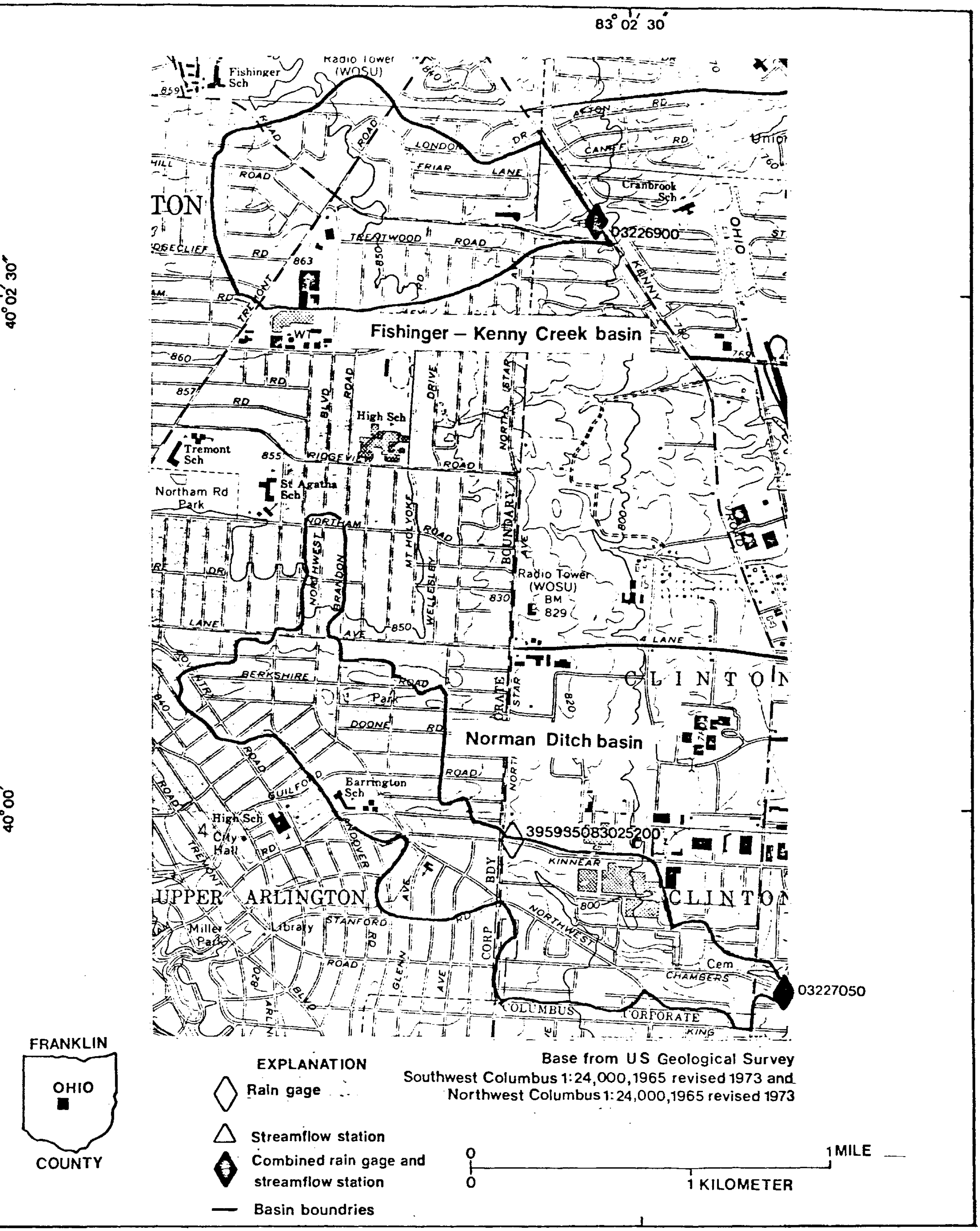


Figure 1.--Location of streamflow and rain gage stations for Fishinger-Kenny Creek and Norman Ditch, Columbus, Ohio, water year 1978-79.

03226900.—Rain gage and streamflow station. Fishinger-Kenny creek at the intersection of Kenny and Fishinger Roads, Lat. 40°01'25", Long. 83°02'30" in the northwest 1/4 of T.1 N., R.18 W. in Upper Arlington, Ohio (Northwest Columbus, 1:24,000 quadrangle).

03227050.—Rain gage and streamflow station. Norman Ditch on Chambers Circle, off Chambers Road, 500 ft. east of intersection with Kenny Road, Lat. 39°59'35", Long 83°02'02" in southwest 1/4 of T.1 N., R.18 W. in Columbus, Ohio (Southwest Columbus, 1:24,000 quadrangle).

395935083025200.—Rain gage. Kinnear Road near intersection with North Star Road, Lat. 39°59'55", Long. 83°02'52", in southwest 1/4 of T.1 N., R.18 W. in Columbus, Ohio (Southwest Columbus 1:24,000 quadrangle).

## Basin Descriptions

03226900.—The Fishinger and Kenny Creek basin has a length of 1.0 mi. and an average width of 0.4 mi. The stream flow is easterly discharging into the Olentangy River. The basin land use is predominantly residential with small areas of rural and commercial land use. The stream channel itself is only about 0.25 mi long with the remainder of the basin drained by storm sewers. The streamflow and sampling station is located on the upstream end of the culvert that passes under Kenny Road.

03227050.—The Norman Ditch basin has a length of 0.8 mi and an average width of 0.33 mi. The stream flows southeasterly and discharges into the Olentangy River. The basin land use is a mixture of single-family and multi-family residences along with commercial and light industrial developments. The stream channel is only open in two places and is predominantly fed by storm sewers. The first open channel is 1.0 mi upstream from the streamflow station and is ponded near an apartment complex. The streamflow station is located on the upstream side of the culvert that passes under Chambers Circle. The sampling station is located on the downstream side of the same culvert with the intake in a small ponded section of the stream. The rain gage is located, near the center of the basin, on Ohio State University property near the southeast corner of the intersection of Kinnear Road and North Star Road.

## Basin Characteristics

Characteristics used to describe the two drainage basins are defined below, as modified from Miller and McKenzie (1978, p. 3-8), and listed in table 1. Also figure 2 shows a map of the basins land use, and figure 3 is an aerial photograph of the basins.

Drainage area.—Area of basin (AREA), in square miles, planimetered from Geological Survey topographic maps. Basin boundaries were determined by first outlining drainage divides on 7 1/2-minute quadrangle maps and then adjusting for storm-sewer diversions according to information from city and county agencies. A field determination was made where sewer intakes were undefined or where drainage divides could not be determined on 7 1/2-minute maps.

Basin slope.—The average slope of the basin (BSLOPE), described by Wisler and Brater (1959), in percent, calculated from Geological Survey 7 1/2-minute topographic maps. The basin slopes were computed by:

Table 1.—Basin characteristics.

| Station | Drainage area ($mi^2$) | Basin slope (percent) | Channel slope (ft/mi) | Basin shape factor | Impervious area (percent) | Land use, in percent | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Rural | single family | multi-family | commercial |
| Fishinger-Kenny Creek | 0.45 | 1.8 | 76 | 2.4 | 60 | 6.2 | 79.3 | 1.4 | 13.1 |
| Norman Ditch | 0.60 | 2.3 | 67 | 5.6 | 85 | 3.9 | 53.2 | 20.4 | 22.5 |

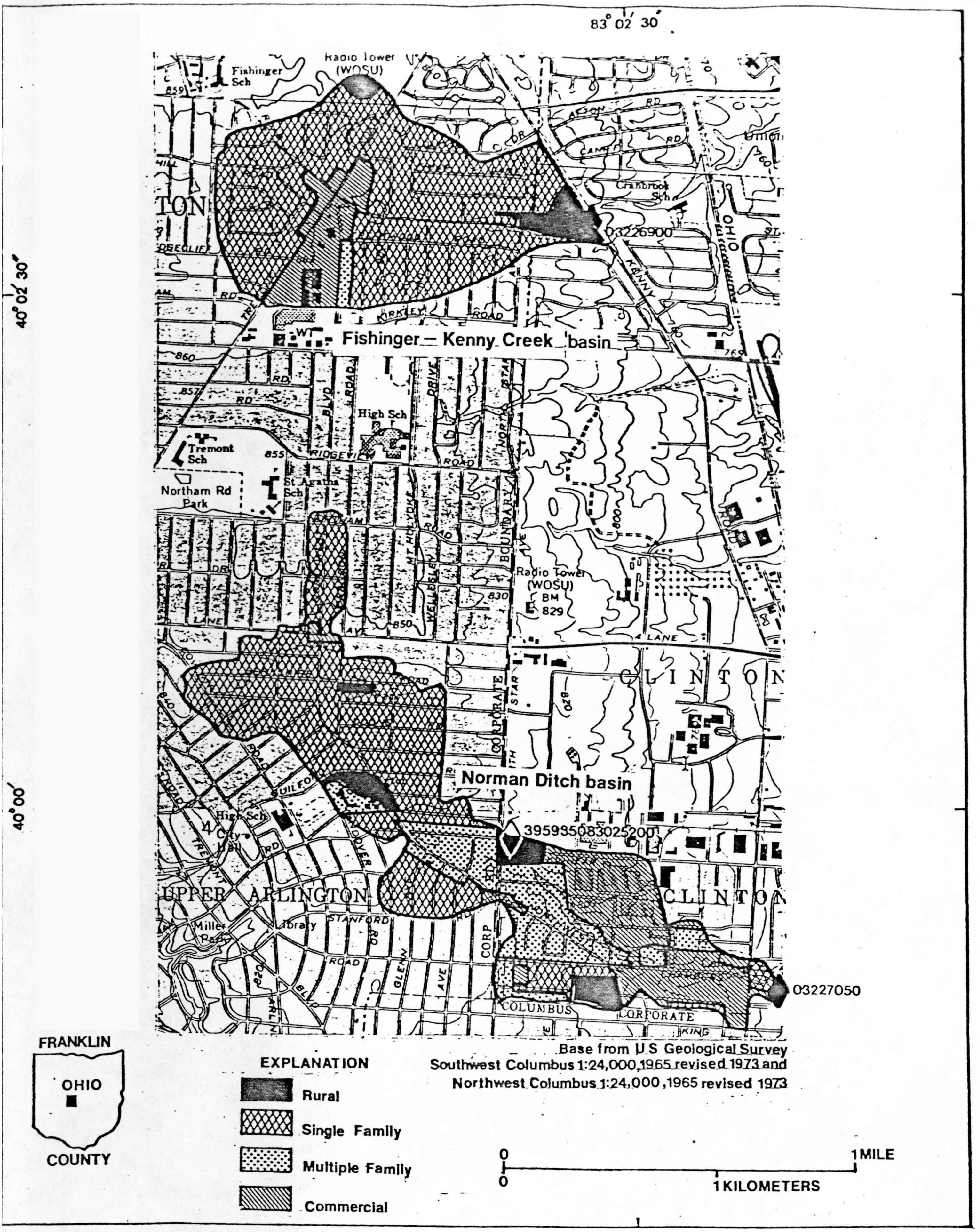


Figure 2.—Land use, Fishinger-Kenny Creek basin and Norman Ditch basin, Columbus, Ohio, water year 1978-79.

$$BSLOPE=DL/A \times 100 \qquad (1)$$

where

D= contour interval, in feet,

L= total length of contours, in feet, and

A= drainage area of the basin, in square feet.

Channel slope.-- The channel slope (CHNSLOP), in feet per mile, for the basin as determined from 7 1/2-minute topographic maps. Channel slope was defined as the difference in elevation between points at the streamflow station and the last point in the stream channel that is open, divided by the distance between the two points.

Impervious area.—Percentage of the basin impervious to infiltration of rain (IMPAREA), such as asphalt roads, paved parking lots, and roofs. The area was determined from aerial photographs (scale: 1:24000) taken in 1976.

Land use.—Percentage of the basin, with land use of types I through IV as mapped from field surveys. Land-use types are defined below:

I. Rural (LU!)- includes all undeveloped land, agricultural land, parks, cemeteries, and school playgrounds.

II. Single-family residential (LU2)-Includes single-family detached dwellings, and duplexes.

III.Multifamily residential (LU3)-Includes multifamily housing units

IV. Commercial (LU4)-Includes general wholesale and retail buildings, school buildings, churches, and light industry.

Basin shape.—The ratio of the length to average width (BASHAPE), described by Office of Water Data Coordination in chapter 7 (1977) was calculated using the formula:

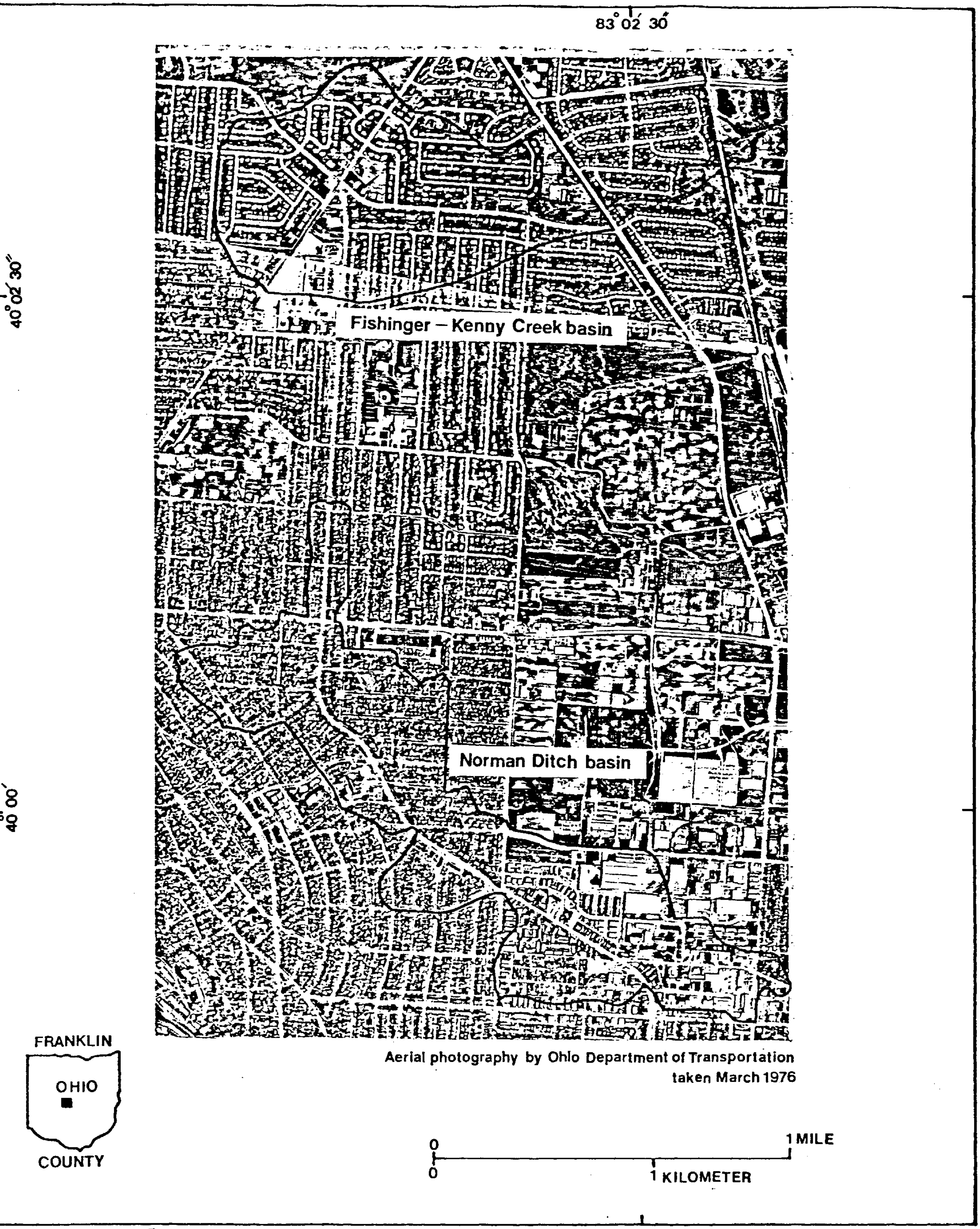


Figure 3.--Aerial photograph, Fishinger-Kenny Creek basin and Norman Ditch basin, Columbus, Ohio, water year 1978-79.

$$BASHAPE = (lc)2/A \qquad (2)$$

where;

Lc = straight-line distance from the basin outlet to the point on the basin divide used to measure the main channel length, and

A = area of drainage basin

# DATA COLLECTION

## Equipment

### Rainfall and stage

Rainfall and stream stage data were collected for each site at 5 minute intervals and recorded to the nearest 0.01 inch. Two rain gages were installed at each station. At Fishinger and Kenny Creek a 6 ft. long, 3 in. inner diameter metal pipe with a 5 in. by 10 in. rainfall collector were mounted on the house and a timer, battery, and digital recorder hooked to a float in the pipe were used to record water surface levels. A tipping bucket rain gage was also mounted on the roof, of the house, to compare with the other rain gage. At Norman Ditch a similar rain gage was installed near the center of the basin and a tipping bucket rain gage was installed on a post near the sampling and streamflow site. At both stations stream stage data were collected by the use of an automatic digital recorder and timer, hooked to a float in a 3 in. stilling well attached to the headwall of the culvert.

## Water Quality Samples

Water quality samples are taken by the U.S. Geological Survey Urban Hydrology Monitor and Sampler. The Urban Hydrology Monitor controls the

Table 2.—Analysis were made for the following constituents.

1. Physical characteristics
   a. Specific conductance
   b. Temperature*
   c. Turbidity
   d. Dissolved solids
   e. Suspended solids
2. Chemical characteristics
   a. pH
   b. Dissolved oxygen
   c. Hardness as $CaCO_3$
   d. Hardness, non-carbonate
   e. Bicarbonate as $HCO_3$
   f. Carbonate as $CaCO_3$
   g. Alkalinity as $CaCO_3$
   h. Dissolved carbon dioxide
3. Biochemical oxygen demand
   a. Chemical oxygen demand
   a. Total organic carbon
4. Bacteriological characteristics
   a. Fecal coliform*
   b. Fecal streptocci*
5. Trace metals
   a. Arsenic
   b. Cadmium
   c. Chromium
   d. Copper
   e. Lead
   f. Nickel
   g. Zinc
6. Major nutrients
   a. Nitrite and nitrate
   b. Ammonia as nitrogen
   c. Ammonia and organic nitrogen
   d. Total organic nitrogen
   e. Total nitrogen as N
   f. Total nitrogen as $NO_3$
   g. Total phosphorus
7. Major ions
   a. Calcium
   b. Magnesium
   c. Iron
   c. Sodium
   d. Potassium
   e. Sulfate
   f. Chloride
   g. Iron
8. Other
   a. Oil and grease

*Analysis made only periodically

timing of the sampling operation by the use of preset record levels, sampling levels, and sampling intervals. The monitor receives its stream stage data from the upstream recorder, and its rainfall data from the tipping bucket Two liter samples are taken and stored in the refrigerator compartment of the sampler until collected for analysis. The U.S.G.S. Urban Hydrology Monitor outputs to a 16-channel paper tape recorder that records time, sample taken, gage height, rainfall, in 5 min intervals for the duration of a storm. A water quality monitor is also utilized to record conductivity, pH, and temperature in 5 min. intervals.

### Sampling Guidelines

In order to get good representative samples to define a quality curve for a storm the U.S.G.S. Urban Hydrology Monitor was set at different sampling intervals depending upon the season or type of storm expected. These sampling intervals ranged from 5 min. to 15 min..

After an event the paper tapes from the Urban Monitor and Water Quality Monitor were read by a Mitron Translator into a Hewlett Packard mini-computer, which printed a listing and graphical representation of time verses discharge, rainfall, conductivity, water temperature, and pH. This listing and graphical representation were used as the basis for selection of representative samples to be sent to the U.S.G.S. Central Lab, in Atlanta, Georgia.

## ANALYSIS OF CONCENTRATIONS

### Variation of concentrations

The first method of analysis includes a study of the range and median values of constituent concentrations and a comparison of constituent concentrations with Ohio Environmental Protection Agency standards.

The ranges and median values of concentrations for 35 constituents are shown in Table 3. Concentrations were generally in normal ranges with a few exceptions. The storm of January 25, 1978 showed high values of conductivity, dissolved solids, sodium, and chloride for both stations. These values are much higher then normally found in the rest of the data. Since this is the only winter storm sampled this points to road salting operations as the cause. For both stations concentrations of metals (cadmium, chromium, copper, iron, lead, nickel, and zinc) were generally high with Norman Ditch having higher values then Fishinger-Kenny Creek. A possible explanation for this is the presence of a metal plating and stamping operation and a truck terminal with maintenance and washing facilities just upstream from the sampling station. Both stations show high concentrations of iron, lead, and zinc and could be indicative of the volume of traffic in these areas. Total organic carbon concentrations are moderate to high at Fishinger-Kenny Creek and high at Norman Ditch, and could indicate contamination by oils, tars, leaves, and grass. The hardness of the water at Fishinger-Kenny Creek is moderately hard and at Norman Ditch is moderately hard to hard.

## Ohio EPA Water Quality Standards

The concentrations of the constituents were compared with the Ohio Enviromental Protection Agency's water quality standards. The warm-habitat standards for the Olentangy River near Columbus Ohio were used because both streams in the study are inflows into the Olentangy River. The warm water habitat standards are summarized in Table 4 and the results of the comparisons are summarized in Table 5. It must be pointed out that both

Table 3 .--Range of concentrations of all constituents for both stations from January 1978 to December 1979.

| | 03226900 Fishinger-Kenny Road Creek at Upper Arlington, Ohio | | | | 03227050 Norman Ditch at Chambers Circle at Columbus, Ohio | | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Median | Number of analysis | Maximum | Minimum | Median | Number of analysis |
| Instantaneous streamflow ($ft^3/s$) ------ | 172 | 1.2 | 8.2 | 100 | 46 | 0.5 | 12 | 94 |
| Specific conductance (micromhos) ------ | 2600 | 46 | 164 | 100 | 2850 | 52 | 300 | 95 |
| pH (units) -------------------------- | 8.5 | 6.4 | 7.2 | 99 | 8.1 | 6.1 | 7.4 | 95 |
| Turbidity (NTU) ---------------------- | 125 | 5 | 24 | 99 | 150 | 5 | 50 | 94 |
| Chemical oxygen demand (mg/L) --------- | 360 | 5 | 50.5 | 96 | 1400 | 0.0 | 80 | 89 |
| Hardness as $CaCO_3$ (mg/L) ------------- | 460 | 21 | 56 | 95 | 340 | 0.0 | 97 | 90 |
| Noncarbonate hardness as $CaCO_3$ (mg/L) - | 160 | 0 | 16.5 | 88 | 120 | 0.0 | 34.5 | 82 |
| Dissolved calcium (mg/L) -------------- | 120 | 5.7 | 18 | 95 | 90 | 13 | 30 | 88 |
| Dissolved magnesium (mg/L) ------------ | 38 | 0.8 | 3.1 | 95 | 29 | 1.7 | 6.3 | 89 |
| Dissolved sodium (mg/L) --------------- | 500 | 1.4 | 7.8 | 95 | 540 | 3.5 | 17 | 89 |
| Dissolved potassium (mg/L) ------------ | 7.5 | 0.5 | 1.4 | 95 | 5.6 | 1.0 | 2.3 | 89 |
| Bicarbonate as $HCO_3$ (mg/L) ------------ | 370 | 14 | 48 | 90 | 310 | 20 | 82 | 82 |
| Carbonate as $CO_3$ (mg/L) --------------- | 16 | 0 | 0 | 89 | 0.0 | 0.0 | 0.0 | 82 |
| Alkalinity as $CaCO_3$ (mg/L) ------------ | 303 | 11 | 39 | 90 | 254 | 16 | 67 | 82 |
| Dissolved carbon dioxide (mg/L) ------- | 140 | 1.6 | 4.3 | 89 | 29 | 0.5 | 6.3 | 82 |
| Dissolved sulfate (mg/L) -------------- | 93 | 3.3 | 16 | 97 | 110 | 7.8 | 32 | 90 |
| Dissolved chloride (mg/L) ------------- | 780 | 1.4 | 13 | 97 | 850 | 5.0 | 26 | 90 |
| Dissolved solids (mg/L) --------------- | 1410 | 32 | 108 | 97 | 1520 | 65 | 195 | 89 |

Table 3.--Range of concentrations of all constituents for both stations from January 1978 to December 1979.--Continued

| Chemical constituents | 03226900 Fishinger-Kenny Road Creek at Upper Arlington, Ohio | | | | 03227050 Norman Ditch at Chambers Circle at Columbus, Ohio | | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Median | Number of analysis | Maximum | Minimum | Median | Number of analysis |
| Suspended solids (mg/L) ------- | 648 | 1 | 49.5 | 96 | 2270 | 0.0 | 67 | 89 |
| Total $NO_2$+ $NO_3$ as N (mg/L)----- | 3.8 | 0.23 | 1 | 96 | 2.5 | 0.0 | 0.76 | 89 |
| Total ammonia as N (mg/L) ----- | 2.4 | 0 | 0.11 | 96 | 13 | 0.01 | 0.12 | 86 |
| Total organic as N (mg/L)------ | 19 | 0.16 | 1.1 | 96 | 17 | 0.49 | 1.5 | 86 |
| Ammonia + organic as N (mg/L)-- | 21 | 0.39 | 1.3 | 96 | 17 | 0.61 | 1.6 | 86 |
| Total nitrogen as N (mg/L)----- | 23 | 0.7 | 2.7 | 96 | 17 | 1.0 | 2.6 | 86 |
| Total nitrogen as $NO_3$ (mg/L)--- | 100 | 3.1 | 12 | 96 | 75 | 4.5 | 11.5 | 86 |
| Total phosphorus (mg/L) ------- | 13 | 0.05 | 0.2 | 96 | 7.7 | 0.09 | 0.35 | 86 |
| Total arsenic (ug/L)----------- | 5 | 0 | 1 | 97 | 15 | 0.0 | 0.30 | 90 |
| Total cadmium (ug/L)----------- | 19 | 0 | 1 | 97 | 12 | 0.0 | 1.0 | 90 |
| Total chromium (ug/L)---------- | 70 | 10 | 10 | 97 | 200 | 10.0 | 20.0 | 90 |
| Total copper (ug/L)------------ | 240 | 2 | 30 | 97 | 1000 | 3.0 | 57 | 90 |
| Total iron (ug/L)-------------- | 20,000 | 170 | 1500 | 97 | 70,000 | 400 | 3300 | 90 |
| Total lead (ug/L)-------------- | 1200 | 0 | 98 | 97 | 2900 | 2.0 | 130 | 90 |
| Total nickel (ug/L)------------ | 49 | 0 | 13 | 97 | 62 | 1.0 | 15 | 90 |
| Total zinc (ug/L)-------------- | 1100 | 50 | 220 | 97 | 3100 | 20 | 245 | 90 |
| Total organic carbon (mg/L)---- | 80 | 2.8 | 9.1 | 95 | 53 | 2.4 | 13 | 90 |

Table 4.--Ohio Environmental Protection Agency warm water standards for the Olentangy River near Columbus Ohio.

Standards for copper, nickel, zinc based on hardness:

| Hardness (mg/l as CaCo ) | Copper (mg/l) | Nickel (mg/l) | Zinc (mg/l) |
|---|---|---|---|
| 0 - 80 | 0.005 | 0.045 | 0.040 |
| 81 - 120 | 0.010 | 0.045 | 0.055 |
| 121 - 160 | 0.015 | 0.100 | 0.070 |
| 161 - 180 | 0.020 | 0.155 | 0.095 |
| 181 - 200 | 0.025 | 0.215 | 0.155 |
| 201 - 220 | 0.030 | 0.270 | 0.130 |
| 221 - 240 | 0.040 | 0.295 | 0.150 |
| 241 - 260 | 0.050 | 0.315 | 0.175 |
| 261 - 280 | 0.060 | 0.340 | 0.205 |
| 281 - 300 | 0.075 | 0.365 | 0.235 |
| 301 - 320 | 0.085 | 0.385 | 0.275 |
| 321 - 340 | 0.115 | 0.410 | 0.320 |
| 341 and above | 0.145 | 0.435 | 0.365 |

Standards for other constituents;

| | |
|---|---|
| Cadmium | 0.012 mg/l |
| Chromium | 0.100 mg/l |
| Dissolved solids | 1500 mg/l |
| Iron | 1.00 mg/l |
| Lead | 0.030 mg/l |
| Oil and grease | 5.00 mg/l |
| pH | < 6.5 or 9.0< |

Table 5.—Comparison of constituents with Ohio Environmental Protection Agency warm water standards for Olentangy River.

| Site | Constituents | Number of analyses | Number of analyses exceeded standards | Standards | Standards exceeded (maximum) | Standards exceeded (median) |
|---|---|---|---|---|---|---|
| Fishinger-Kenny Road Creek | Cadmium (mg/l) | 97 | 1 | 0.012 | 0.007 | — |
| | Chromium (mg/l) | 97 | 0 | 0.100 | — | — |
| | Copper (mg/l) | 95 | 84 | * | 0.23 | 0.026 |
| | Dissolved solids (mg/l) | 97 | 0 | 1500 | — | — |
| | Iron (mg/l) | 97 | 60 | 1.00 | 19.0 | 2.65 |
| | Lead (mg/l) | 97 | 75 | 0.030 | 1.17 | 0.11 |
| | Nickel (mg/l) | 97 | 0 | * | — | — |
| | Oil and grease (mg/l) | 4 | 0 | 5.0 | — | — |
| | pH (units) | 99 | 1 | 6.5-9.0 | 0.10 | — |
| | Zinc (mg/l) | 95 | 90 | * | 1.06 | 0.18 |
| Norman Ditch | Cadmium (mg/l) | 90 | 1 | 0.012 | — | — |
| | Chromium (mg/l) | 90 | 2 | 0.100 | 0.10 | 0.07 |
| | Copper (mg/l) | 90 | 86 | * | 0.99 | 0.046 |
| | Dissolved solids (mg/l) | 89 | 1 | 1500 | 43 | — |
| | Iron (mg/l) | 90 | 80 | 1.00 | 69.0 | 3.0 |
| | Lead (mg/l) | 90 | 79 | 0.030 | 2.87 | 0.13 |
| | Nickel (mg/l) | 90 | 3 | * | 0.017 | 0.013 |
| | Oil and grease (mg/l) | 7 | 0 | 5.0 | — | — |
| | pH (units) | 95 | 1 | 6.5-9.0 | 0.4 | — |
| | Zinc (mg/l) | 90 | 84 | * | 3.05 | 0.18 |

* Standard varies with hardness. See table 4.

Norman Ditch and Fishinger - Kenny Creek only account for approximately 0.1% of the flow of the Olentangy River so the effects of contamination from these two basins on the Olentangy River are minimal, but the results of these two basins multiplied by the many small urban streams can contribute strongly to the pollution of the Olentangy River. Of all the constituents copper, iron, lead, and zinc are, by far, the ones that exceeded their standards.

## BIVARIATE CORRELATION AND REGRESSION ANALYSIS OF CONSTITUENTS

Bivariate correlations and regression analysis is the second analytical method used in this study. The degree of association between two variables is defined by bivariate correlation coefficients. Care must be exercised because correlation coefficients are mathematical associations and do not always imply true associations. Only correlation coefficients greater then + 0.70 are considered significant and are listed. Bivariate regression equations were generated for all significant correlations and are of the form:

$$Y = b + mX \qquad (3)$$

where

$Y$ = the dependent variable,

$b$ = the constant,

$m$ = the coefficient, and

Bivariate correlations and regression equations were generated in order to better understand associations between constituents and to augment the data sets for storms or to estimate missing data.

Table 6 shows a key to abbreviations used in Table 7, which is a listing of regression equations, correlation coefficients, standard error of estimate of the regression equation, standard deviation of the dependent variable, and the number of analysis used. No useful equations, for either station, were derived using conductivity, pH, discharge, or turbidity as independent variables, Equations using these parameters would be the only useful equations to augment data. The regression equations listed show valid chemical relationships. Figures 4 and 5 show the relationships between conductivity and dissolved solids for Fishinger-Kenny Creek and Norman Ditch and figures 6 and 7 show the relationships between sodium and chloride for Fishinger-Kenny Creek and Norman Ditch. These 4 relationships illustrate the best regression equations for these stations.

## MULTIPLE REGRESSION ANALYSIS

The third analytical approach used was multiple-linear regression analysis, to relate storm yields of chemical constituents (dependent variables) to antecedent conditions, and storm conditions (independent variables). This approach identifies the independent variables which affect the chemical concentration during storm events.

Table 6.—Key to abbreviations used in correlations and bivarite regression analysis

| Abbreviations | Description | Unit |
|---|---|---|
| C | Specific conductance | Micromhous |
| P | pH | Units |
| H | Hardness | Mg/l |
| Ca | Dissolved calcium | Mg/l |
| M | Dissolved magnesium | Mg/l |
| N | Dissolved sodium | Mg/l |
| K | Dissolved potassium | Mg/l |
| B | Bicarbonate | Mg/l |
| Co | Dissolved carbon dioxide | Mg/l |
| Cl | Dissolved chloride | Mg/l |
| Ds | Dissolved solids | Mg/l |
| S | Dissolved sulfate | Mg/l |

Table 7.—Bivariate regression equations for both stations

| Equation | Correlation coefficients | Standard error of estimates | Standard deviation | Number of analysis |
|---|---|---|---|---|
| | | Fishinger-Kenny Creek | | |
| Ds = 19.7 + .573 C | .99 | 30.8 | 192 | 97 |
| H = 30.5 + .336 Ds | .77 | 53.4 | 83.9 | 95 |
| B = 6.92 + .731 H | .97 | 14.3 | 61.4 | 88 |
| Ca = 10.5 + .090 Ds | .79 | 13.4 | 21.9 | 95 |
| Ca = .978 + 1.10 S | .95 | 6.93 | 21.9 | 95 |
| Ca = 2.94 + .260 H | 1.00 | 1.45 | 21.9 | 95 |
| M = 1.06 + .027 Ds | .74 | 4.82 | 7.09 | 95 |
| M = -2.20 + .349 S | .93 | 2.65 | 7.09 | 95 |
| M = -1.72 + .084 H | .99 | .797 | 7.09 | 95 |
| N = -21.7 + .226 Ds | .84 | 28.8 | 52.2 | 95 |
| N = -1.27 + .614 Cl | .99 | 8.38 | 52.2 | 95 |
| N = -19.7 + .138 C | .88 | 25.0 | 52.2 | 95 |
| | | Norman Ditch | | |
| Ds = 31.6 + .545 C | .98 | 29.4 | 171 | 89 |
| B = 8.80 + .771 H | .91 | 22.0 | 53.2 | 82 |
| Co = 77.2 - 9.51 P | -.79 | 2.45 | 3.96 | 82 |
| Ca = 3.94 + .256 H | .99 | 2.05 | 15.5 | 88 |
| Ca = 6.49 + .762 S | .92 | 6.13 | 15.5 | 88 |
| M = -2.43 + .088 H | .98 | 1.12 | 5.39 | 89 |
| M = -1.94 + .272 S | .94 | 1.77 | 5.39 | 89 |
| N = -37.2 + .171 C | .93 | 20.8 | 56.7 | 89 |
| N = -42.6 + .293 Ds | .88 | 27.1 | 56.7 | 88 |
| N = -.380 + .630 Cl | 1.00 | 3.82 | 57.0 | 89 |
| K = 1.08 + .039 S | .72 | .704 | 1.02 | 89 |
| Cl = -58.4 + .272 C | .93 | 32.3 | 89.3 | 90 |

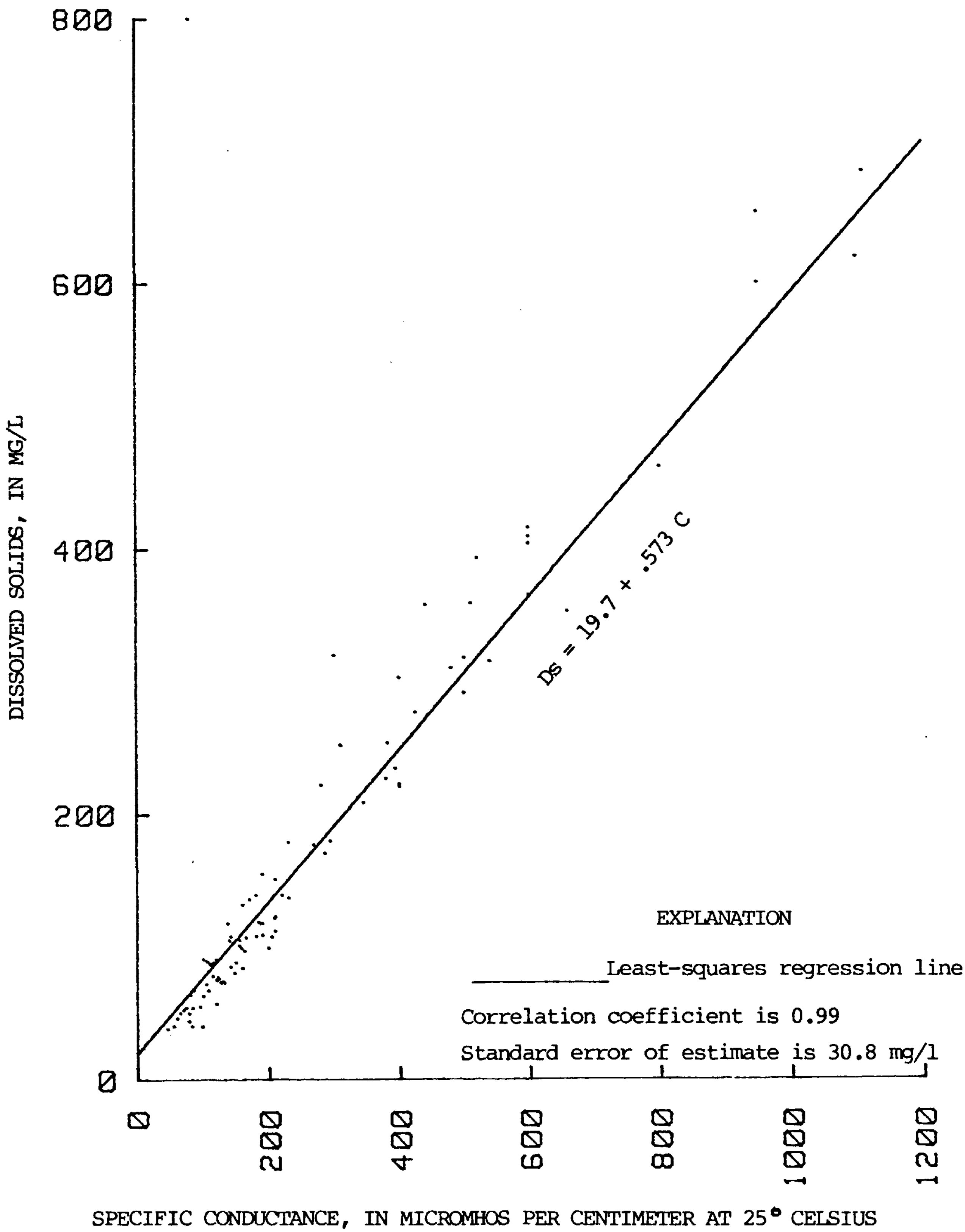


Figure 4.—Relationship between specific conductance and dissolved solids for Fishinger-Kenny Road Creek.

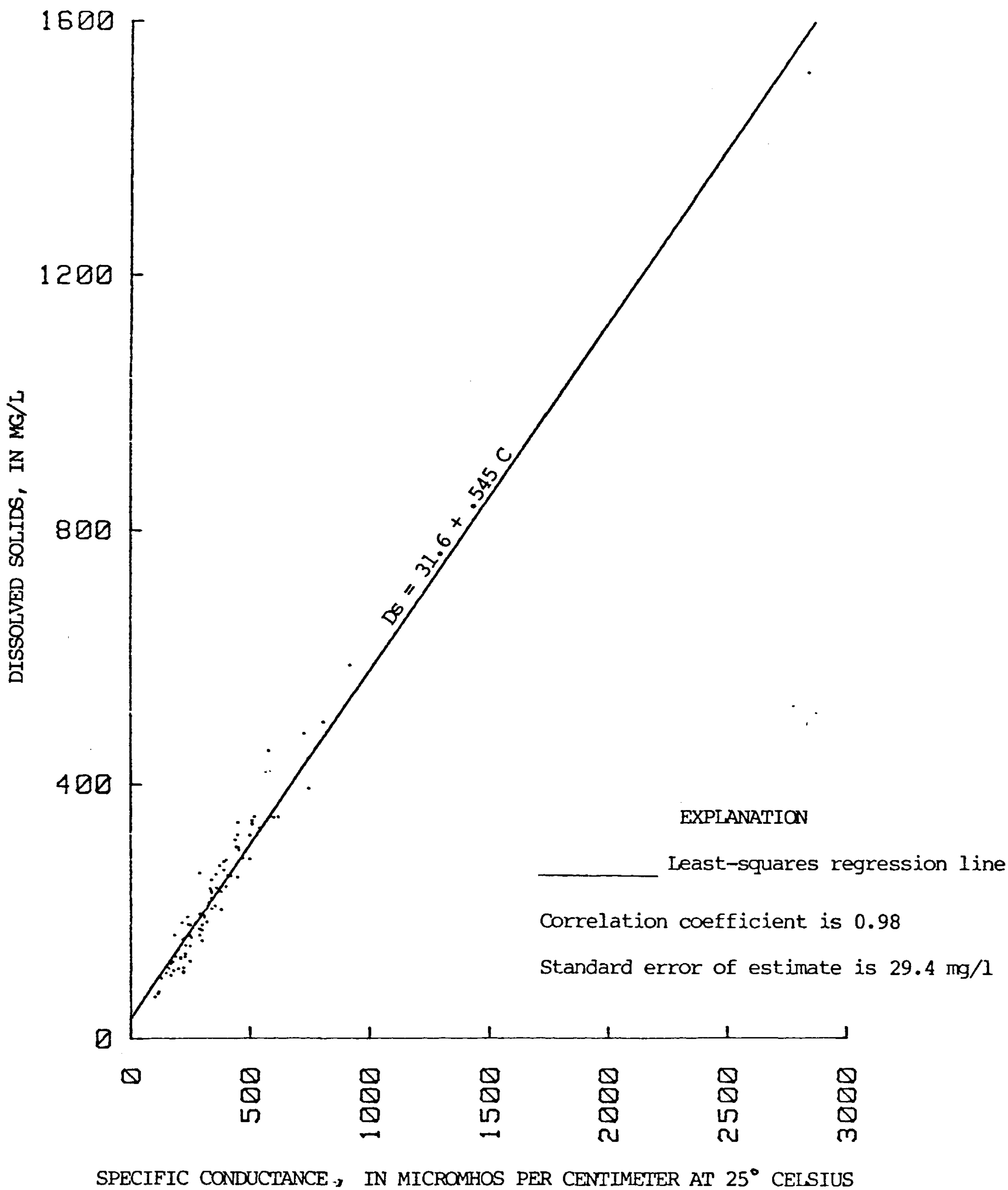


Figure 5.—Relationship between specific conductance and dissolved solids for Norman Ditch.

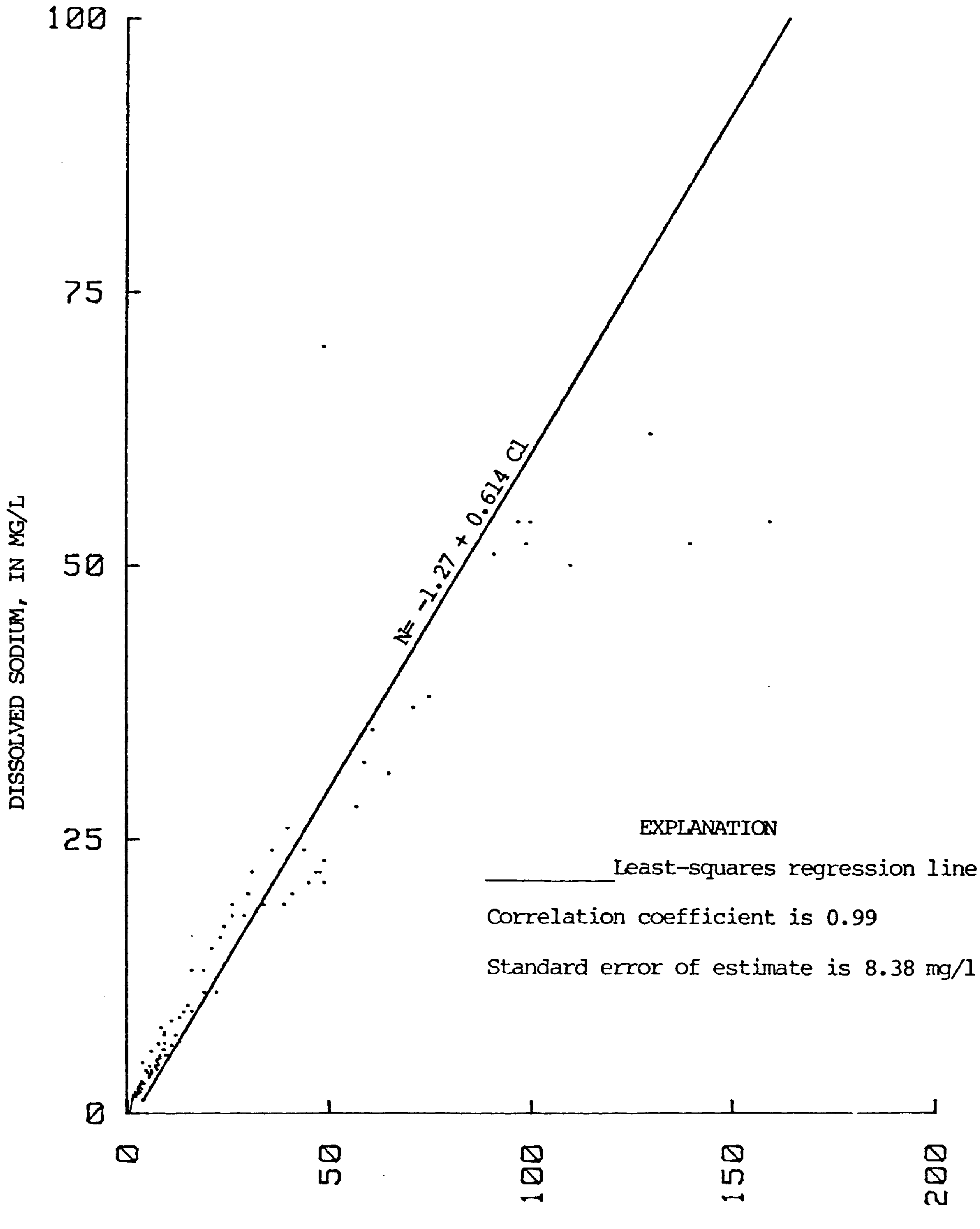


Figure 6.--Relationship between dissolved chloride and dissolved sodium for Fishinger-Kenny Rd. Creek.

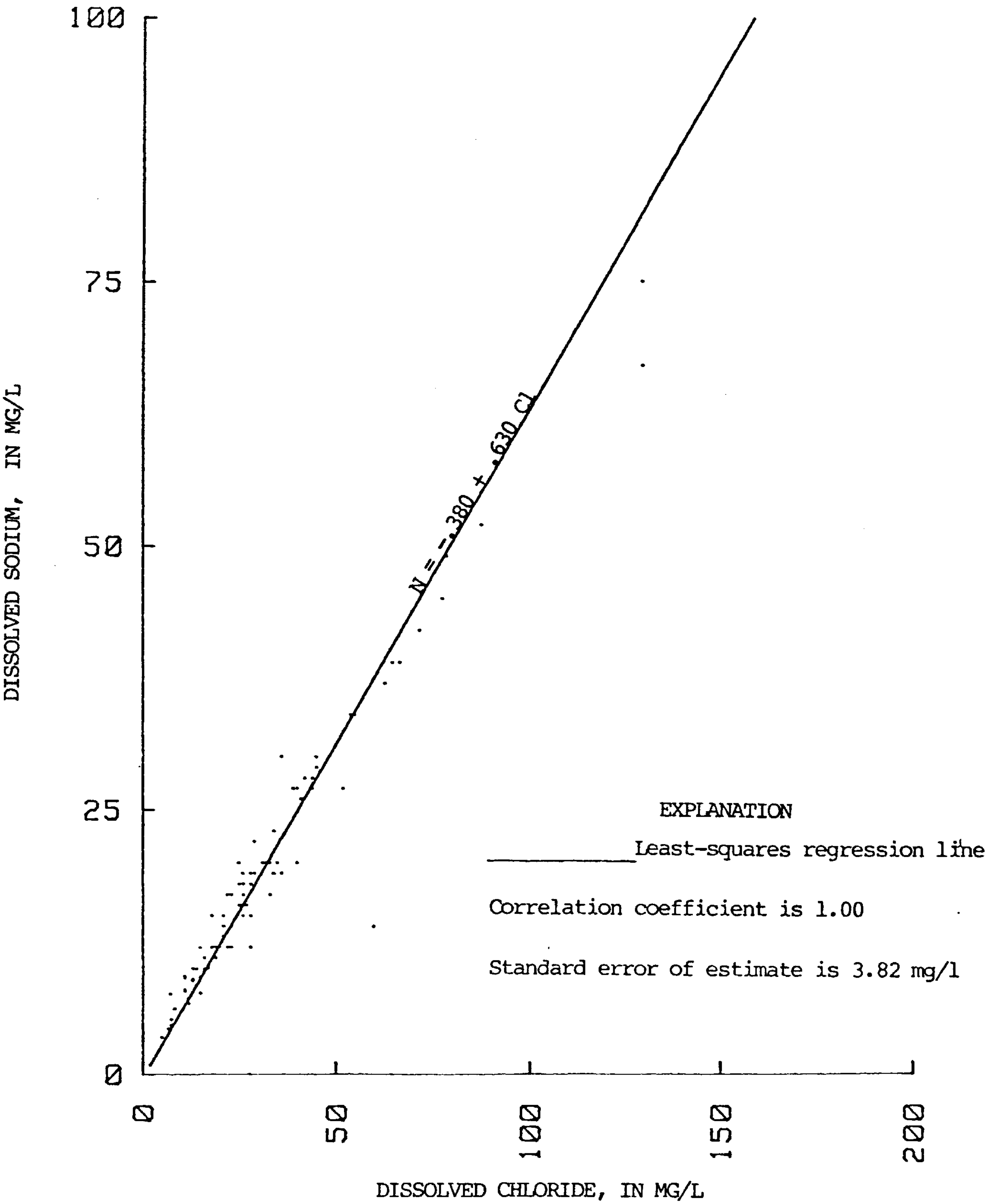


Figure 7.--Relationship between dissolved chloride and sodium for Norman Ditch.

## Yield Calculations

Yield calculations were performed by a computer program written for the Hewlett Packard 9845A micro-computer. Storm yields were computed by summing incremental 5 min discharges with corresponding chemical concentrations using 1/2 the interval from the previous sample (or starting time of the storm) to 1/2 the interval to the subsequent sample (or ending time of the storm). The resulting formulas are shown below:

$$\text{storm yield}=K/A\sum_{n=1}^{n} Q_j C_j$$

For variables:

Q =sum of 5 min intervals of discharge for time period of sample j ($ft^2/s$).

c =concentration of sample j.

n=number of samples taken for storm.

A=drainage area of basin.

K=constant to convert yield units where:

K= 9.35X10-6 for all constituents

All yields were in tons per square mile and then converted into tons per square mile per inch of rainfall.

## Multiple regression computation

The mutiple regression analysis was performed by the Hewlett Packard 9845A computer using the HP system 45 statistical software package (Deane). The stepwise forward selection algorithm, using Cholesky square root procedure was used to select independent variables for the regression equations. The regression equations are of the form:

$$Y = a + b_1X_1 + b_2X_2 + \dots b_nX_n \tag{4}$$

$$\log Y = \log a + b_1\log X_1 + b_2\log x_2 \dots b_n\log X_n \tag{5}$$

where

| | |
|---|---|
| Y | = the dependent variable |
| X ...X | = the independent variable |
| b ...b | = the regression coefficients, |
| a | = the regression constant, and |
| n | = the number of variables. |

Table 8 is a list of independent variables used in the regression analysis and, except for SMI14D, were taken from Miller and McKenzie (1978). Table 9 is a listing, by storm events, of the values of the independent variables used. A constant of one was added to all variables used in the log transform regression analysis so logs of 0 were not possible. The regression analysis was run for both stations using both linear and log transform equations.

Combinations of independent variables were automatically selected which had F values greater then 3.00. Guide lines for selection of good regression equations were:

1. Standard error of estimate smaller then standard deviation of the dependent variable.

2. Regression equations of independent variables had the lowest standard error of estimate.

3. Two or more independent variables should not have high correlation

Table 8.--List of independent variables used in regression analysis.

| Abbreviation | Explanation | Units |
|---|---|---|
| 1. RFPR14D | Rainfall in 14-day period prior to storm | Inches |
| 2. RFPR48H | Rainfall in 48-hour period prior to storm | Do. |
| 3. RFPR24H | Rainfall in 24-hour period prior to storm | Do. |
| 4. H15MRPR48 | Highest 15-minute rainfall intensity in the previous 48 hours | In/h. |
| 5. DRYDAYS | Time interval before storm with less then 0.1 inch of rain, or the hours to a prior 1-hour period that exceeded 0.02 inch in 1 hour period | Hours |
| 6. SMI14D | Soil moisture index, calculated for prior 14 day period using equation; $$\text{SMI14D} = \sum_{i=1}^{14} 0.9^{i} \; P_i \qquad (4)$$ where $P_i$ = rainfall on the i day preceding the storm | Inches. |
| 7. TRSTM | Total rainfall of the storm | Do. |
| 8. TRUSTM | Total runoff of the storm | Do. |
| 9. H5MRFI | Highest 5-minute rainfall intensity | In/h. |
| 10. H15MRFI | Highest 15-minute rainfall intensity | Do. |
| 11. H1HRFI | Highest 1-hour rainfall intensity | Do. |
| 12. H6HRFI | Highest 6-hour rainfall intensity, or average intensity if the storm was less then 6 hours | Do. |
| 13. H15MXQ | The time period between the highest 15-minute rainfall intensity and the maxmium discharge | Minutes |
| 14. H15MCHQ | The time period between the highest 15-minute rainfall intensity and the maxmium positive 15-minute change in discharge | Do. |
| 15. STMMIN | The duration of sampling period used to calculate the storm load | Do. |

Modified from Miller and McKenzie (1978, p. 37)

Table 9.--Values for independent variables used in regression analysis

| | Date | RFPR14D | RFPR48H | RFPR24H | H15MRPR48 | DRYDAYS | SMI14D | TRSTM | TRUSTM | H5MRFI | H15MRFI | H1HRFI | H6HRFI | H15MXQ | H15MCHQ | STMMIN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fishinger-Kenny Creek | May 16, 1978 | 1.28 | 0.23 | 0.00 | 0.88 | 32.0 | 1.31 | 0.24 | 0.09 | 0.36 | 0.32 | 0.16 | .004 | 15 | 5 | 405 |
| | June 7, 1878 | 0.10 | 0.00 | 0.00 | 0.00 | 103 | 0.07 | 0.25 | 0.06 | 0.72 | 0.56 | 0.23 | .004 | 5 | 5 | 100 |
| | July 23, 1978 | 0.16 | 0.00 | 0.00 | 0.00 | 172 | 0.06 | 0.27 | 0.09 | 1.44 | 0.88 | 0.26 | .010 | 5 | 5 | 80 |
| | August 6, 1978 | 1.01 | 0.20 | 0.20 | 0.28 | 16 | 0.47 | 0.33 | 0.06 | 0.96 | 0.68 | 0.31 | .025 | 100 | 10 | 55 |
| | August 30, 1978 | 1.07 | 0.24 | 0.02 | 0.88 | 40 | 0.70 | 0.75 | 0.20 | 0.60 | 0.40 | 0.25 | .125 | 15 | 10 | 380 |
| | November 23, 1978 | 1.28 | 0.00 | 0.00 | 0.00 | 98 | 0.50 | 0.22 | 0.06 | 0.36 | 0.32 | 0.17 | .004 | 40 | 30 | 185 |
| | March 31, 1979 | 0.37 | 0.06 | 0.03 | 0.08 | 156 | 0.20 | 0.23 | 0.06 | 0.84 | 0.40 | 0.24 | .010 | 50 | 10 | 120 |
| | April 1, 1979 | 0.77 | 0.40 | 0.04 | 0.40 | 34 | 0.54 | 0.24 | 0.04 | 0.36 | 0.24 | 0.14 | .008 | 90 | 35 | 115 |
| | April 4,1979 | 1.62 | 0.23 | 0.00 | 0.92 | 44 | 1.05 | 0.60 | 0.22 | 0.48 | 0.40 | 0.26 | .009 | 45 | — | 295 |
| | June 6, 1979 | 2.01 | 0.04 | 0.04 | 0.04 | 108 | 0.79 | 0.31 | 0.12 | 0.36 | 0.20 | 0.17 | .005 | 100 | 10 | 250 |
| | August 1, 1979 | 2.48 | 0.01 | 0.00 | 0.04 | 89 | 1.38 | 0.36 | 0.12 | 2.40 | 0.92 | 0.34 | .077 | 10 | 5 | 130 |
| | August 5,1979 | 2.98 | 0.03 | 0.03 | 0.08 | 12 | 1.24 | 0.30 | 0.08 | 1.32 | 0.68 | 0.25 | .008 | 15 | 15 | 125 |
| | August 20, 1979 | 1.50 | 0.08 | 0.04 | 0.04 | 62 | 0.71 | 1.80 | 0.50 | 4.20 | 2.00 | 1.00 | .038 | 15 | 5 | 185 |
| | August 28, 1979 | 4.41 | 0.20 | 0.00 | 0.08 | 54 | 2.20 | 0.21 | 0.05 | 1.08 | 0.44 | 0.19 | .009 | 25 | 15 | 55 |
| Norman Ditch | April 18,1978 | 0.10 | 0.00 | 0.00 | 0.00 | 274 | 0.23 | 0.44 | 0.12 | 0.36 | 0.24 | 0.18 | .073 | 90 | 30 | 405 |
| | June 7, 1978 | 0.12 | 0.00 | 0.00 | 0.00 | 64 | 0.12 | 0.24 | 0.05 | 0.96 | 0.60 | 0.21 | .004 | 20 | 0 | 120 |
| | August 19, 1978 | 1.53 | 0.00 | 0.00 | 0.00 | 95 | 0.55 | 0.26 | 0.09 | 1.56 | 0.56 | 0.22 | .043 | 40 | — | 150 |
| | August 28, 1978 | 0.51 | 0.01 | 0.01 | 0.04 | 201 | 0.19 | 0.42 | 0.15 | 0.96 | 0.52 | 0.28 | .007 | 20 | — | 205 |
| | August 30, 1978 | 0.99 | 0.26 | 0.04 | 0.76 | 60 | 0.74 | 0.73 | 0.31 | 0.84 | 0.40 | 0.24 | .113 | 20 | 15 | 475 |
| | November 23, 1978 | 0.85 | 0.00 | 0.00 | 0.00 | 69 | 0.47 | 0.15 | 0.02 | 0.72 | 0.36 | 0.10 | .003 | 40 | 25 | 190 |
| | March 31, 1979 | 0.52 | 0.08 | 0.03 | 0.08 | 156 | 0.26 | 0.35 | 0.05 | 0.84 | 0.40 | 0.25 | .058 | 55 | 15 | 265 |
| | July 9, 1979 | 1.92 | 0.33 | 0.33 | 0.52 | 5 | 0.95 | 0.16 | 0.10 | 0.84 | 0.36 | 0.12 | .027 | 50 | 45 | 270 |
| | August 1, 1979 | 2.88 | 0.22 | 0.21 | 0.84 | 1 | 1.40 | 0.36 | 0.08 | 2.40 | 0.92 | 0.34 | .008 | 20 | 10 | 180 |
| | August 5, 1979 | 3.17 | 0.02 | 0.02 | 0.08 | 91 | 1.23 | 0.30 | 0.12 | 1.32 | 0.68 | 0.25 | .005 | 40 | 10 | 240 |
| | August 28, 1979 | 4.05 | 0.18 | 0.01 | 0.12 | 35 | 2.19 | 0.28 | 0.12 | 0.96 | 0.56 | 0.18 | .005 | 40 | 5 | 255 |

coefficients.

4. R values of 80% or better.

(Riggs, 1977, p. 9-18)

Table 10 lists the results of the linear and log-transform regressions. Fishinger-Kenny Creek has six good regressions and Norman Ditch has two. The reason for this might be the fact that there is a higher percentage of commercial land-use in the Norman Ditch basin (22.5%) then there is in the Fishinger-Kenny Creek basin (13.1%), also the discharge of waste from the metal plating and stamping operation in the basin of Norman Ditch might affect the concentrations of constituents. The log-transform equations better explains the storm yields then the linear equation. Only one linear equation was good but the R-squared value and the standard error of estimate of the log equations for nitrite and nitrate explains the yields better then the linear equations do.

The regression equations do reveal the important independent variables affecting storm yields of constituents. The lag time variable show up in all the equations. The time period between the maximum 15-minute rainfall intensity and the maximum change in discharge (H15MCHQ) shows an inverse relationship with yields whereas the time period between the maximum 15-minute rainfall intensity and the maximum discharge (H15MXQ) shows a direct relationship.

The antecedent variables of rainfall in a 14-day period prior to the storm (RFPR14D), rainfall in previous 48-hour period prior to the storm (RFPR48H), rainfall intensity in the previous 48 hours prior to the storm (H15MRPR48) all show inverse relationships to yields. The independent variables of dry hours before the storm (DRYDAYS) and soil moisture index (SMI14D) show direct relationships. These antecedent paramters indicate

Table 10.—Linear and log-transform multiple-regression equations for both stations.

| Station | Basin yields | Type of model | Equation | R | Standard deviation of yields | Standard error estimate |
|---|---|---|---|---|---|---|
| Fishinger-Kenny Creek | Nitrite+nitrate | Linear | .039 - .001 H15HMCHQ - .257 H6HRFI + .023 H15MPR48 - .125 RFPR24H | .81 | .016 | .009 |
| Fishinger-Kenny Creek | Nitrite+nitrate | Log | .004 - .50x10 Log H15MCHQ - .007 Log H15MXQ -.126 Log H6HRFI | .88 | .016 | .006 |
| Fishinger-Kenny Creek | Total organic Nitrogen | Log | .113 - .79x10 Log H15MCHQ - .014 Log H15HXQ -.034 Log RFPR14D - .042 Log H15MPR48 | .82 | .030 | .015 |
| Fishinger-Kenny Creek | Nitrogen | Log | .161 - .13x10 Log H15MCHQ - .022 Log H15MXQ - .036 Log RFPR14D - .052 Log H15MPR48 | .80 | .043 | .023 |
| Fishinger-Kenny Creek | Nickel | Log | .00018 - .72x10 Log H15HCHQ + .0001 Log DRYDAYS | .80 | .0002 | .0001 |
| Fishinger-Kenny Creek | Chromium | Log | .0006 + .003 Log TRSTM - .003 Log H6HRFI + .00009 Log H15MXQ + .0001 Log DRYDAYS | .89 | .0003 | .0001 |
| Norman Ditch | Copper | Log | .0029 - .014 Log H1HRFI - .13x10 Log H15MCHQ + .002 Log H5MRFI | .93 | .0008 | .0002 |
| Norman Ditch | Ammonia | Log | .048 - .012 Log STMMIN + .059 Log TRSTM + .005 Log H15MXQ - .003 Log SMI14D | .91 | .0024 | .0009 |

that antecedent conditions of a storm are important to the constituent yields.

## CONCLUSIONS

This study has helped in the development and modification of equipment for sampling urban water quality, the development of computer programs for fast analysis of storm events and quality data, and the development of techniques to better use the equipment. The use of the three analytical approaches were helpful in understanding the relationships between constituents concentrations and the basin characteristics, antecedent conditions, and storm conditions. Each of the approaches are summarized below.

### Concentration Analysis

In general, constituent concentrations were within acceptable limits with the exceptions of the metals. Total organic carbon indicates some contamination of the streams. There is some seasonal contamination, notably by sodium chloride in the winter and phosphorus in the spring.

### Correlation Analysis

In both basins there are several strong correlations between constituents but the use of regression equations for augmentation of data for either stream is not possible because of few strong correlations with discharge, conductance, pH, or turbidity.

### Multiple-Regression Analysis

In general, regression equations showed several important independent variables that influence constituent yields during storm events. More data is needed to improve the regression analysis. Data from different basins in the Columbus Ohio area is needed so basin characteristics can be used as independent variables in the regression equations.

## Suggestions for Future Data Collection Efforts

1. Collect more data within the two basins.

2. Collect data from many different basins in the Columbus area, using basins with a greater range of land uses and basin characteristics.

3. Collect rainfall samples for quality analysis to determine the amount of contamination from atmospheric sources.

4. Collect street sweeping samples for quality analysis to determine the amount of dust-fall within the basins.

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## BASIC DATA

The basic data section of this report is arranged in two sections. The first section contains four tables showing constituent yields for individual storms. Tables 11 and 12 are computed in tons per square mile and tables 13 and 14 are computed in tons per square mile per inch of rainfall. The second section includes graphs of rainfall intensity, streamflow, and constituent concentrations for individual storms. Samples that were taken are marked by circles on the hydrographs, showing the time of sampling. Figures 8 to 32 are storm events for Fishinger-Kenny Road Creek and figures 33 to 47 are storm events for Norman Ditch. Storm events are arranged in chronological order.

Table 11.--Constituent yields of individual storms for Fishinger-Kenny Road Creek (measured in tons per square mile).

| Date of storm | Chemical oxygen demand | Hardness | Dissolved calcium | Dissolved mag-nesium | Dissolved sodium | Dissolved potassium | Bicar-bonate | Alka-linity | Dissolved carbon dioxide |
|---|---|---|---|---|---|---|---|---|---|
| May 16, 1978 | .36 | .56 | .16 | .037 | .069 | .0078 | .50 | .41 | .027 |
| June 7, 1978 | .26 | .68 | .20 | .048 | .091 | .017 | .53 | .44 | .012 |
| July 23, 1978 | .81 | .28 | .088 | .013 | .040 | .012 | .18 | .14 | .014 |
| August 6, 1978 | .094 | .11 | .038 | .0043 | .0074 | .0034 | .11 | .092 | .014 |
| August 30, 1978 | .38 | .41 | .13 | .021 | .050 | .014 | .46 | .38 | .058 |
| November 23, 1978 | .17 | .28 | .084 | .017 | .026 | .010 | .23 | .19 | .026 |
| March 31, 1979 | .86 | .24 | .075 | .012 | .082 | .0028 | .20 | .16 | .018 |
| April 1, 1979 | .24 | .15 | .047 | .0080 | .054 | .0020 | .13 | .11 | .011 |
| April 4, 1979 | — | 3.3 | .92 | .24 | .81 | .034 | 2.8 | 2.3 | .10 |
| June 6, 1979 | .27 | .43 | .14 | .024 | .070 | .0079 | .40 | .33 | .025 |
| August 1, 1979 | .73 | .83 | .24 | .057 | .11 | .014 | .67 | .55 | .10 |
| August 5, 1979 | .33 | .26 | .083 | .013 | .030 | .0053 | .23 | .19 | .053 |
| August 20, 1979 | 2.3 | 1.3 | .41 | .063 | .11 | .047 | 1.1 | .88 | .15 |
| August 28, 1979 | .077 | .11 | .036 | .0054 | .0095 | .0029 | .072 | .060 | .012 |

Table 11.—Constituent yields of individual storms for Fishinger-Kenny Road Creek (measured in tons per square mile) continued.

| Date of storm | Dissolved Sulfate | Dissolved chloride | Dissolved solids | Suspended solids | Ammonia (as N $x10^{-3}$) | Total organic nitrogen ($x10^{-3}$) | Total nitrogen ($x10^{-3}$) | Total nitrogen (as $NO_3$ $x10^{-3}$) | Total phosphrous ($x10^{-3}$) |
|---|---|---|---|---|---|---|---|---|---|
| May 16, 1978 | .12 | .12 | .89 | .72 | .63 | 6.6 | 15 | 68 | 1.1 |
| June 7, 1978 | .20 | .19 | 1.3 | .38 | 3.6 | 29 | 43 | 190 | 1.0 |
| July 23, 1978 | .088 | .058 | .62 | 1.8 | .85 | 16 | 24 | 100 | 2.4 |
| August 6, 1978 | .026 | .0090 | .20 | .57 | 1.9 | 3.9 | 8.3 | 36 | .96 |
| August 30, 1978 | .082 | .071 | .98 | .37 | .46 | 7.6 | 15 | 180 | 1.0 |
| November 23, 1978 | .073 | .044 | .48 | .15 | .30 | 3.8 | 8.2 | 36 | .83 |
| March 31, 1979 | .075 | .12 | .51 | .017 | .26 | 11 | 14 | 61 | 2.1 |
| April 1, 1979 | .048 | .077 | .34 | .24 | .12 | 4.3 | 6.3 | 27 | .65 |
| April 4, 1979 | .68 | 1.5 | 6.2 | 2.2 | 2.1 | 47 | 90 | 390 | 4.9 |
| June 6, 1979 | .10 | .10 | .73 | .26 | .93 | 4.2 | 11 | 52 | .96 |
| August 1, 1979 | .22 | .24 | 1.6 | 2.0 | 2.0 | 19 | 30 | 130 | 5.7 |
| August 5, 1979 | .068 | .049 | .54 | .061 | 1.1 | 3.4 | 9.3 | 42 | 8.7 |
| August 20, 1979 | .48 | .16 | 2.0 | 7.1 | 9.2 | 55 | 95 | 420 | 7.8 |
| August 28, 1979 | .043 | .013 | .17 | .19 | 1.3 | 1.7 | 6.4 | 28 | .47 |

Table 11.—Constituent yields of individual storms for Fishinger-Kenny Road Creek (measured in tons per square mile) continued.

| Date of storm | Total Arsenic ($x10^{-3}$) | Total cadmium ($x10^{-3}$) | Total chromium ($x10^{-3}$) | Total copper ($x10^{-3}$) | Total iron ($x10^{-3}$) | Total lead ($x10^{-3}$) | Total nickel ($x10^{-3}$) | Total zinc ($x10^{-3}$) | Total organic ($x10^{-3}$) |
|---|---|---|---|---|---|---|---|---|---|
| May 16, 1978 | .010 | .00 | .070 | .14 | 18 | 1.3 | .090 | 1.2 | .046 |
| June 7, 1978 | .010 | .00 | .040 | .080 | 4.8 | .030 | .050 | .50 | .046 |
| July 23, 1978 | .010 | .00 | .060 | .25 | 54 | 2.0 | .14 | 2.4 | .047 |
| August 6, 1978 | .00 | .010 | .070 | .13 | 20 | 1.0 | .060 | 1.0 | .030 |
| August 30, 1978 | .010 | .010 | .15 | .45 | 8.4 | .69 | .070 | 1.5 | .077 |
| November 23, 1978 | .00 | .00 | .040 | .91 | 3.2 | .35 | .070 | 1.2 | .059 |
| March 31, 1979 | .010 | .010 | .16 | .41 | 50 | 2.9 | .12 | 2.8 | .11 |
| April 1, 1979 | .00 | .010 | .050 | .17 | 18 | .88 | .040 | .95 | .030 |
| April 4, 1979 | .040 | .030 | .41 | 1.4 | 180 | 6.6 | .58 | 6.7 | — |
| June 6, 1979 | .010 | .010 | .19 | .13 | 5.9 | .43 | .10 | .87 | .054 |
| August 1, 1979 | .040 | .020 | .090 | .55 | 32 | 2.1 | .090 | 2.4 | .13 |
| August 5, 1979 | .020 | .040 | .070 | .12 | 2.7 | .26 | .040 | .46 | .041 |
| August 20, 1979 | .070 | .11 | 2.1 | 2.5 | 2000 | 4.8 | .65 | 8.0 | .54 |
| August 28, 1979 | .00 | .00 | .030 | .050 | 4.4 | .19 | .03 | .62 | .024 |

Table 12.--Constituent yields of individual storms for Norman Ditch (measured in tons per square mile).

| Date of storm | Chemical oxygen demand | Hardness | Dissolved calcium | Dissolved mag-nesium | Dissolved sodium | Dissolved potassium | Bicar-bonate | Alka-linity | Dissolved carbon dioxide |
|---|---|---|---|---|---|---|---|---|---|
| April 18, 1978 | .90 | -- | .20 | .040 | .15 | .015 | -- | -- | -- |
| June 7, 1978 | .51 | .39 | .12 | .023 | .055 | .015 | .35 | .29 | .031 |
| August 19, 1978 | .75 | .75 | .22 | .048 | .094 | .019 | .53 | .43 | .047 |
| August 28, 1978 | .90 | 1.0 | .30 | .068 | .13 | .028 | .76 | .62 | .085 |
| August 30, 1978 | 1.4 | 1.4 | .42 | .080 | .15 | .038 | 1.4 | 1.1 | .10 |
| November 23, 1978 | .092 | .29 | .077 | .023 | .034 | .0062 | .19 | .16 | .014 |
| March 31, 1979 | .91 | .35 | .10 | .022 | .11 | .0060 | .30 | .25 | .023 |
| July 9, 1079 | .53 | .62 | .15 | .056 | .082 | .012 | .56 | .46 | .036 |
| August 1, 1979 | .50 | .67 | .19 | .045 | .087 | .015 | .62 | .50 | .016 |
| August 5, 1979 | .50 | .73 | .22 | .046 | .073 | .017 | .62 | .51 | .029 |
| August 28, 1979 | .94 | 1.4 | .38 | .10 | .16 | .022 | 1.2 | 1.0 | .047 |

Table 12.--Constituent yields of individual storms for Norman Ditch (measured in tons per square mile)continued.

| Date of storm | Dissolved sulfate | Dissolved chloride | Dissolved solids | Suspended solids | Ammonia (as N $x10^{-3}$) | Total organic nitrogen ($x10^{-3}$) | Total nitrogen ($x10^{-3}$) | Total nitrogen (as NO $x10^{-3}$) | Total phosphrous ($x10^{-3}$) |
|---|---|---|---|---|---|---|---|---|---|
| April 18, 1978 | .23 | .25 | 1.4 | 1.7 | 1.4 | 21 | 30 | 130 | 4.3 |
| June 7, 1978 | .14 | .083 | .75 | .72 | 1.6 | 15 | 18 | 79 | 2.3 |
| August 19, 1978 | .25 | .17 | 1.4 | 1.0 | 2.4 | 16 | 24 | 100 | 3.2 |
| August 28, 1978 | .38 | .20 | 2.1 | .72 | 2.0 | 18 | 33 | 140 | 3.0 |
| August 30, 1978 | .37 | .29 | 2.8 | 1.2 | 1.8 | 24 | 37 | 160 | 5.1 |
| November 23, 1978 | .11 | .061 | .50 | .12 | .26 | 2.0 | 3.6 | 16 | 1.5 |
| March 31, 1979 | .12 | .17 | .75 | .091 | .24 | 9.8 | 13 | 57 | 2.4 |
| July 9, 1979 | .21 | .13 | 1.2 | 1.6 | .68 | 8.5 | 18 | 78 | 2.2 |
| August 1, 1979 | .21 | .13 | — | .68 | 1.9 | 12 | 17 | 74 | 1.8 |
| August 5, 1979 | .21 | .14 | 1.2 | 1.2 | 1.7 | 15 | 23 | 98 | 2.8 |
| August 28, 1979 | .39 | .25 | 2.2 | 1.6 | 1.9 | 17 | 30 | 140 | 3.6 |

Table 12.--Constituent yields of individual storms for Norman Ditch (measured in tons per square mile)continued.

| Date of storm | Total Arsenic ($x10^{-3}$) | Total cadmium ($x10^{-3}$) | Total chromium ($x10^{-3}$) | Total copper ($x10^{-3}$) | Total iron ($x10^{-3}$) | Total lead ($x10^{-3}$) | Total nickel ($x10^{-3}$) | Total zinc ($x10^{-3}$) | Total organic ($x10^{-3}$) |
|---|---|---|---|---|---|---|---|---|---|
| April 18, 1978 | .030 | .010 | .30 | .54 | 40 | 1.8 | .13 | 3.5 | .068 |
| June 7, 1978 | .020 | .000 | .070 | .28 | 27 | 1.1 | .12 | 1.7 | .062 |
| August 19, 1978 | .030 | .030 | .18 | .87 | 50 | 1.9 | .14 | 2.5 | .18 |
| August 28, 1978 | .020 | .030 | .11 | .77 | 27 | 1.1 | .14 | 2.0 | .14 |
| August 30, 1978 | .050 | .030 | .23 | .88 | 43 | 1.9 | .15 | 3.0 | .18 |
| November 23, 1978 | .000 | .000 | .10 | .38 | 4.1 | .18 | .050 | .41 | .030 |
| March 31, 1979 | .010 | .010 | .040 | .33 | 33 | 1.5 | .070 | 1.7 | .11 |
| July 9, 1979 | .030 | .020 | .27 | .37 | 32 | .97 | .11 | 1.6 | .14 |
| August 1, 1979 | .030 | .000 | .38 | .31 | 19 | .57 | .070 | .41 | .068 |
| August 5, 1979 | .040 | .000 | .28 | .51 | 29 | 1.2 | .070 | 1.5 | .18 |
| August 28, 1979 | .030 | .010 | .080 | .46 | 39 | 1.2 | .13 | 3.1 | .29 |

Table 13.--Constituent yields of individual storms for Fishinger-Kenny Road Creek (measured in tons per square mile per inch of rainfall).

| Date of storm | Chemical oxygen demand | Hardness | Dissolved calcium | Dissolved mag-nesium | Dissolved sodium | Dissolved potassium | Bicar-bonate | Alka-linity | Dissolved carbon dioxide |
|---|---|---|---|---|---|---|---|---|---|
| May 16, 1978 | 1.5 | 2.4 | .66 | .15 | .30 | .032 | 2.1 | 1.7 | .11 |
| June 7, 1978 | 1.0 | 2.7 | .78 | .19 | .36 | .069 | 2.1 | 1.7 | .047 |
| July 23, 1978 | 3.1 | 1.1 | .34 | .051 | .15 | .045 | .68 | .55 | .054 |
| August 6, 1978 | .29 | .34 | .12 | .013 | .022 | .010 | .34 | .28 | .044 |
| August 30, 1978 | .50 | .55 | .18 | .028 | .066 | .019 | .61 | .51 | .078 |
| November 23, 1978 | .79 | 1.3 | .38 | .077 | .12 | .047 | 1.0 | .85 | .12 |
| March 31, 1979 | 3.7 | 1.0 | .33 | .053 | .36 | .012 | .87 | .71 | .078 |
| April 1, 1979 | .98 | .63 | .20 | .033 | .22 | .0082 | .55 | .45 | .045 |
| April 4, 1979 | — | 5.5 | 1.5 | .40 | 1.3 | .057 | 4.7 | 3.9 | .17 |
| June 6, 1979 | .86 | 1.4 | .44 | .076 | .22 | .026 | 1.3 | 1.1 | .082 |
| August 1, 1979 | 2.0 | 2.3 | .66 | .16 | .32 | .039 | 1.9 | 1.5 | .28 |
| August 5, 1979 | 1.1 | .87 | .28 | .043 | .10 | .018 | .78 | .63 | .19 |
| August 20, 1979 | 1.3 | .72 | .23 | .035 | .061 | .026 | .60 | .50 | .082 |
| August 28, 1979 | .38 | .56 | .18 | .027 | .047 | .014 | .36 | .30 | .060 |

Table 13.--Constituent yields of individual storms for Fishinger-Kenny Road Creek (measured in tons per square mile per inch of rainfall)continued.

| Date of storm | Dissolved sulfate | Dissolved chloride | Dissolved solids | Suspended solids | Ammonia (as N $x10^{-3}$) | Total organic nitrogen ($x10^{-3}$) | Total nitrogen ($x10^{-3}$) | Total nitrogen (as NO $x10^{-3}$) | Total phosphrous ($x10^{-3}$) |
|---|---|---|---|---|---|---|---|---|---|
| May 16, 1979 | .52 | .51 | 3.7 | 3.0 | 2.6 | 28 | 62 | 280 | 4.5 |
| June 7, 1978 | .80 | .78 | 5.0 | 1.5 | 14 | 120 | 170 | 740 | 6.4 |
| July 23, 1978 | .34 | .22 | 2.4 | 7.1 | 3.2 | 62 | 92 | 400 | 9.4 |
| August 6, 1978 | .080 | .027 | .60 | 1.7 | 5.8 | 12 | 25 | 110 | 2.9 |
| August 30, 1978 | .11 | .094 | 1.3 | .49 | .62 | 10 | 21 | 240 | 1.4 |
| November 23, 1978 | .33 | .20 | 2.2 | .66 | 1.3 | 17 | 37 | 160 | 3.8 |
| March 31, 1979 | .33 | .50 | 2.2 | .073 | 1.1 | 50 | 60 | 270 | 9.2 |
| April 1, 1979 | .20 | .32 | 1.4 | 1.0 | .51 | 18 | 26 | 113 | 2.7 |
| April 4, 1979 | 1.1 | 2.5 | 10 | 3.7 | 3.5 | 79 | 150 | 650 | 8.2 |
| June 6, 1979 | .31 | .32 | 2.3 | .83 | 3.0 | 14 | 37 | 170 | 3.1 |
| August 1, 1979 | .61 | .68 | 4.4 | 5.7 | 5.6 | 52 | 82 | 370 | 16 |
| August 5, 1979 | .23 | .16 | 1.8 | .20 | 3.6 | 11 | 31 | 140 | 29 |
| August 20, 1979 | .26 | .087 | 1.1 | 3.9 | 5.1 | 31 | 53 | 230 | 4.3 |
| August 28, 1979 | .21 | .067 | .84 | .96 | 6.4 | 8.5 | 32 | 140 | 2.3 |

Table 13.--Constituent yields of individual storms for Fishinger-Kenny Road Creek (measured in tons per square mile per inch of rainfall)continued.

| Date of storm | Total Arsenic ($x10^{-3}$) | Total cadmium ($x10^{-3}$) | Total chromium ($x10^{-3}$) | Total copper ($x10^{-3}$) | Total iron ($x10^{-3}$) | Total lead ($x10^{-3}$) | Total nickel ($x10^{-3}$) | Total zinc ($x10^{-3}$) | Total organic ($x10^{-3}$) |
|---|---|---|---|---|---|---|---|---|---|
| May 16, 1978 | .029 | .016 | .28 | .60 | 75 | 5.3 | .37 | 4.9 | .19 |
| June 7, 1978 | .052 | .000 | .17 | .33 | 19 | .13 | .20 | 2.0 | .16 |
| July 23, 1978 | .040 | .013 | .23 | .96 | 210 | 7.7 | .53 | 9.0 | .18 |
| August 6, 1978 | .013 | .016 | .22 | .40 | 60 | 3.2 | .20 | 3.2 | .090 |
| August 30, 1978 | .019 | .019 | .19 | .59 | 11 | .92 | .087 | 1.9 | .10 |
| November 23, 1978 | .019 | .019 | .19 | 4.2 | 15 | 1.6 | .30 | 5.2 | .27 |
| March 31, 1979 | .023 | .064 | .68 | 1.8 | 220 | 12 | .51 | 12 | .50 |
| April 1, 1979 | .013 | .026 | .19 | .69 | 77 | 3.6 | .18 | 4.0 | .12 |
| April 4, 1979 | .070 | .044 | .68 | 2.3 | 300 | 11 | .96 | 11 | — |
| June 6, 1979 | .027 | .025 | .62 | .43 | 19 | 1.4 | .32 | 2.8 | .18 |
| August 1, 1979 | .11 | .060 | .24 | 1.5 | 90 | 5.9 | .26 | 6.6 | .36 |
| August 5, 1979 | .077 | .13 | .25 | .41 | 9.0 | .85 | .13 | 1.6 | .14 |
| August 20, 1979 | .038 | .061 | 1.2 | 1.4 | 110 | 2.7 | .36 | 4.4 | .30 |
| August 28, 1979 | .016 | .010 | .16 | .27 | 22 | .96 | .15 | 3.1 | .12 |

Table 14.--Constituent yields of individual storms for Norman Ditch(measured in tons per square mile per inch of rainfall).

| Date of storm | Chemical oxygen demand | Hardness | Dissolved calcium | Dissolved mag-nesium | Dissolved sodium | Dissolved potassium | Bicar-bonate | Alka-linity | Dissolved carbon dioxide |
|---|---|---|---|---|---|---|---|---|---|
| April 18, 1978 | 2.0 | — | .45 | .09 | .34 | .034 | — | — | — |
| June 7, 1978 | 2.1 | 1.6 | .51 | .09 | .23 | .061 | 1.5 | 1.2 | .13 |
| August 19, 1978 | 2.9 | 2.9 | .85 | .18 | .36 | .074 | 2.0 | 1.7 | .18 |
| August 28, 1978 | 2.1 | 2.4 | .70 | .16 | .30 | .067 | 1.8 | 1.5 | .20 |
| August 30, 1978 | 1.9 | 1.9 | .57 | .11 | .21 | .051 | 1.9 | 1.5 | .14 |
| November 23, 1978 | .62 | 1.9 | .50 | .15 | .23 | .041 | 1.3 | 1.0 | .094 |
| March 31, 1979 | 2.6 | 1.0 | .30 | .062 | .32 | .017 | .87 | .71 | .067 |
| July 9, 1979 | 3.3 | 3.8 | .96 | .35 | .51 | .078 | 3.5 | 2.9 | .22 |
| August 1, 1979 | 1.4 | 1.9 | .54 | .12 | .24 | .041 | 1.7 | 1.4 | .045 |
| August 5, 1979 | 1.6 | 2.4 | .72 | .15 | .24 | .058 | 2.1 | 1.7 | .096 |
| August 28, 1979 | 3.3 | 4.9 | 1.3 | .37 | .59 | .077 | 4.4 | 3.6 | .17 |

Table 14.--Constituent yields of individual storms for Norman Ditch(measured in tons per square mile per inch of rainfall)continued.

| Date of storm | Dissolved sulfate | Dissolved chloride | Dissolved solids | Suspended solids | Ammonia (as N $x10^{-3}$) | Total organic nitrogen ($x10^{-3}$) | Total nitrogen ($x10^{-3}$) | Total nitrogen (as NO $x10^{-3}$) | Total phosphrous ($x10^{-3}$) |
|---|---|---|---|---|---|---|---|---|---|
| April 18, 1978 | .53 | .56 | 3.1 | 3.8 | 3.2 | 48 | 67 | 300 | 9.7 |
| June 7, 1978 | .57 | .35 | 3.1 | 3.0 | 6.9 | 63 | 74 | 330 | 9.7 |
| August 19, 1978 | .97 | .67 | 5.5 | 4.0 | 9.0 | 60 | 92 | 400 | 12 |
| August 28, 1978 | .91 | .47 | 5.0 | 1.7 | 4.7 | 44 | 78 | 340 | 7.2 |
| August 30, 1978 | .51 | .28 | 3.8 | 1.6 | 2.5 | 32 | 51 | 220 | 7.0 |
| November 23, 1978 | .76 | .40 | 3.3 | .80 | 1.7 | 13 | 24 | 100 | 10 |
| March 31,1979 | .33 | .48 | 2.1 | .26 | .69 | 28 | 37 | 160 | 6.8 |
| July 9, 1979 | 1.3 | .80 | 7.2 | 9.9 | 4.3 | 53 | 110 | 490 | 14 |
| August 1, 1979 | .60 | .37 | -- | 1.9 | 5.3 | 32 | 47 | 200 | 5.0 |
| August 5, 1979 | .71 | .46 | 4.0 | 3.9 | 5.7 | 51 | 77 | 330 | 9.3 |
| August 28, 1979 | 1.4 | .91 | 7.9 | 5.7 | 6.7 | 61 | 110 | 490 | 13 |

Table 14.--Constituent yields of individual storms for Norman Ditch(measured in tons per square mile per inch of rainfall)continued.

| Date of storm | Total Arsenic ($x10^{-3}$) | Total cadmium ($x10^{-3}$) | Total chromium ($x10^{-3}$) | Total copper ($x10^{-3}$) | Total iron ($x10^{-3}$) | Total lead ($x10^{-3}$) | Total nickel ($x10^{-3}$) | Total zinc ($x10^{-3}$) | Total organic ($x10^{-3}$) |
|---|---|---|---|---|---|---|---|---|---|
| April 18, 1978 | .060 | .022 | .67 | 1.2 | 91 | 4.1 | .29 | 8.0 | .15 |
| June 7, 1978 | .077 | .010 | .29 | 1.2 | 110 | 4.6 | .50 | 6.9 | .26 |
| August 19, 1978 | .11 | .098 | .71 | 3.4 | 190 | 7.2 | .53 | 9.6 | .71 |
| August 28, 1978 | .057 | .067 | .26 | 1.8 | 63 | 2.5 | .34 | 4.8 | .32 |
| August 30, 1978 | .062 | .042 | .31 | 1.2 | 59 | 2.7 | .21 | 4.1 | .25 |
| November 23, 1978 | .017 | .020 | .65 | 2.5 | 27 | 1.2 | .35 | 2.7 | .20 |
| March 31, 1979 | .027 | .032 | .11 | .93 | 95 | 4.2 | .21 | 4.8 | .32 |
| July 9, 1979 | .19 | .094 | 1.7 | 2.3 | 200 | 6.0 | .70 | 10 | .85 |
| August 1, 1979 | .080 | .008 | 1.1 | .85 | 52 | 1.6 | .19 | 1.1 | .19 |
| August 5, 1979 | .12 | .010 | .95 | 1.7 | 97 | 4.0 | .25 | 5.0 | .60 |
| August 28, 1979 | .093 | .033 | .30 | 1.6 | 140 | 4.1 | .46 | 11 | 1.0 |

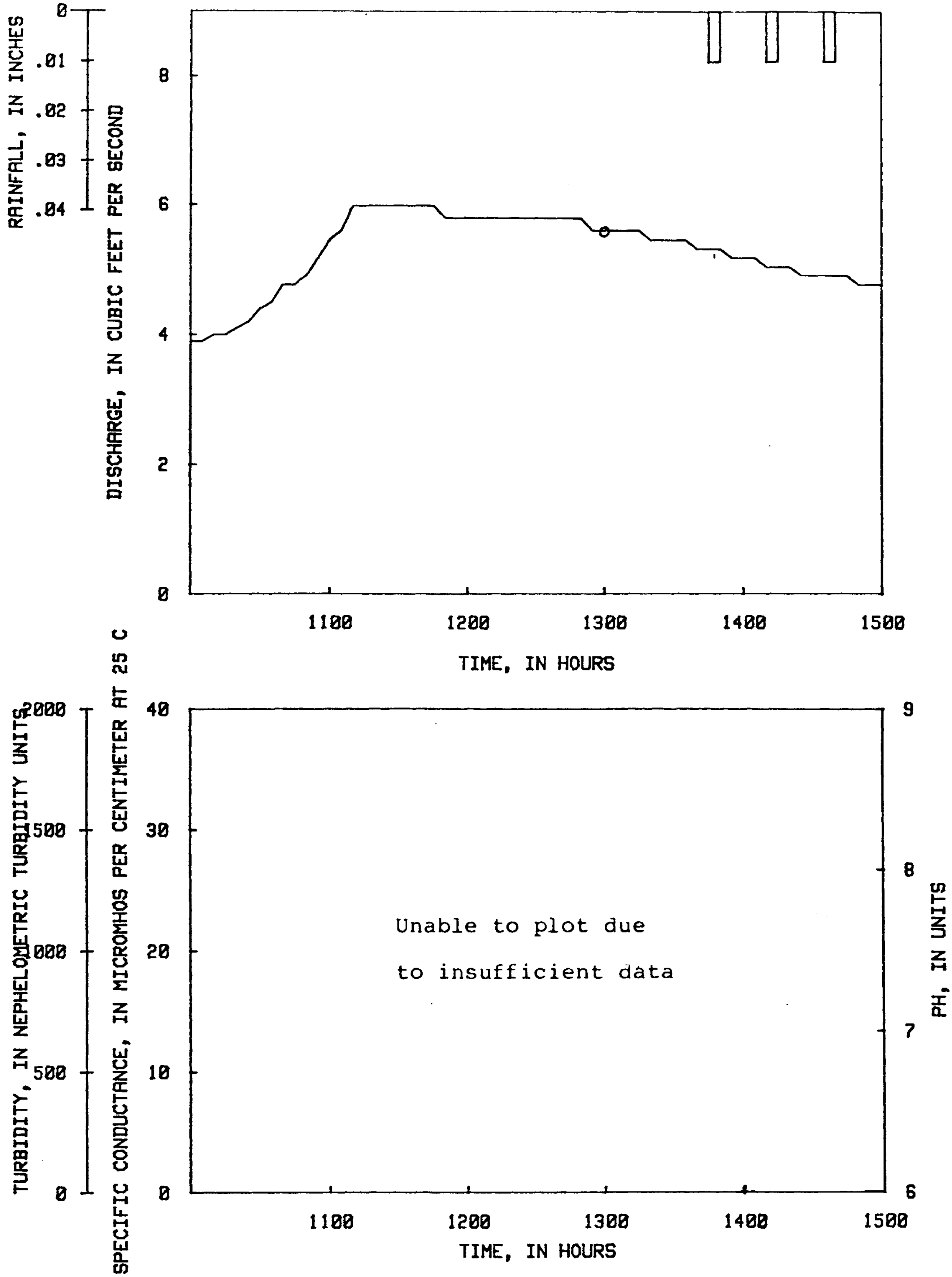



Figure 8.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of January 25, 1978.

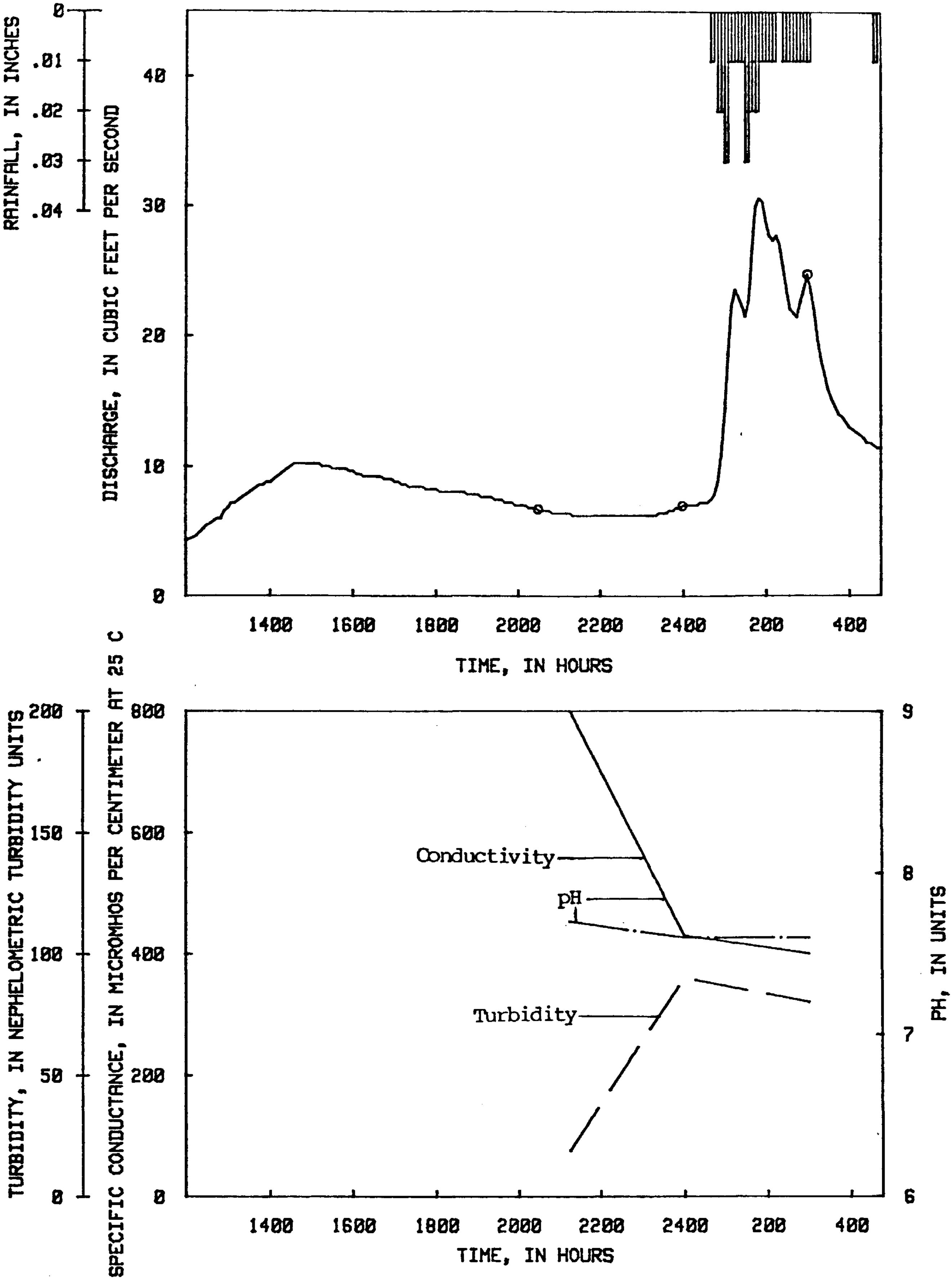



Figure 9.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of March 13, 1978.

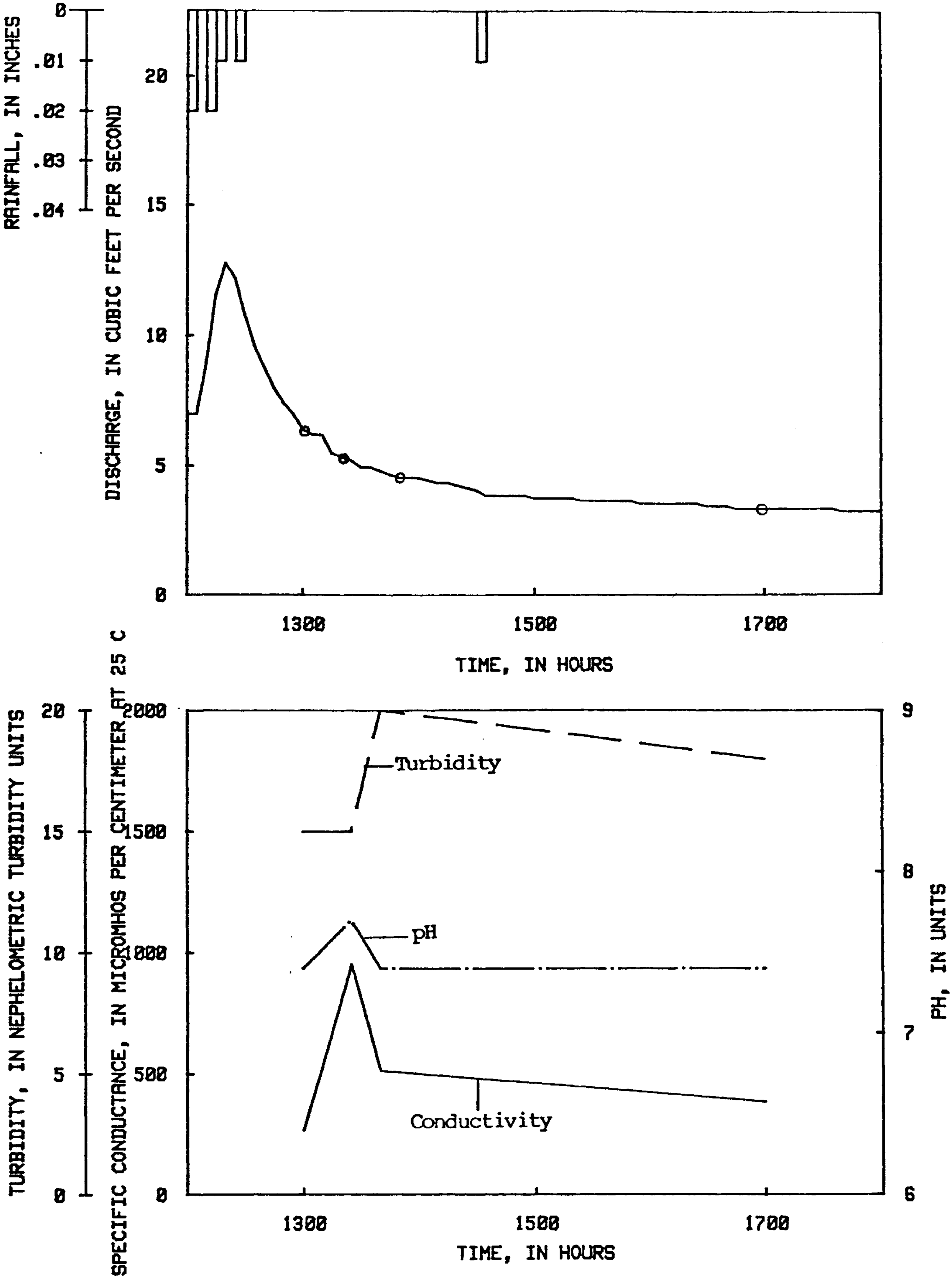



Figure 10.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of April 18, 1978.

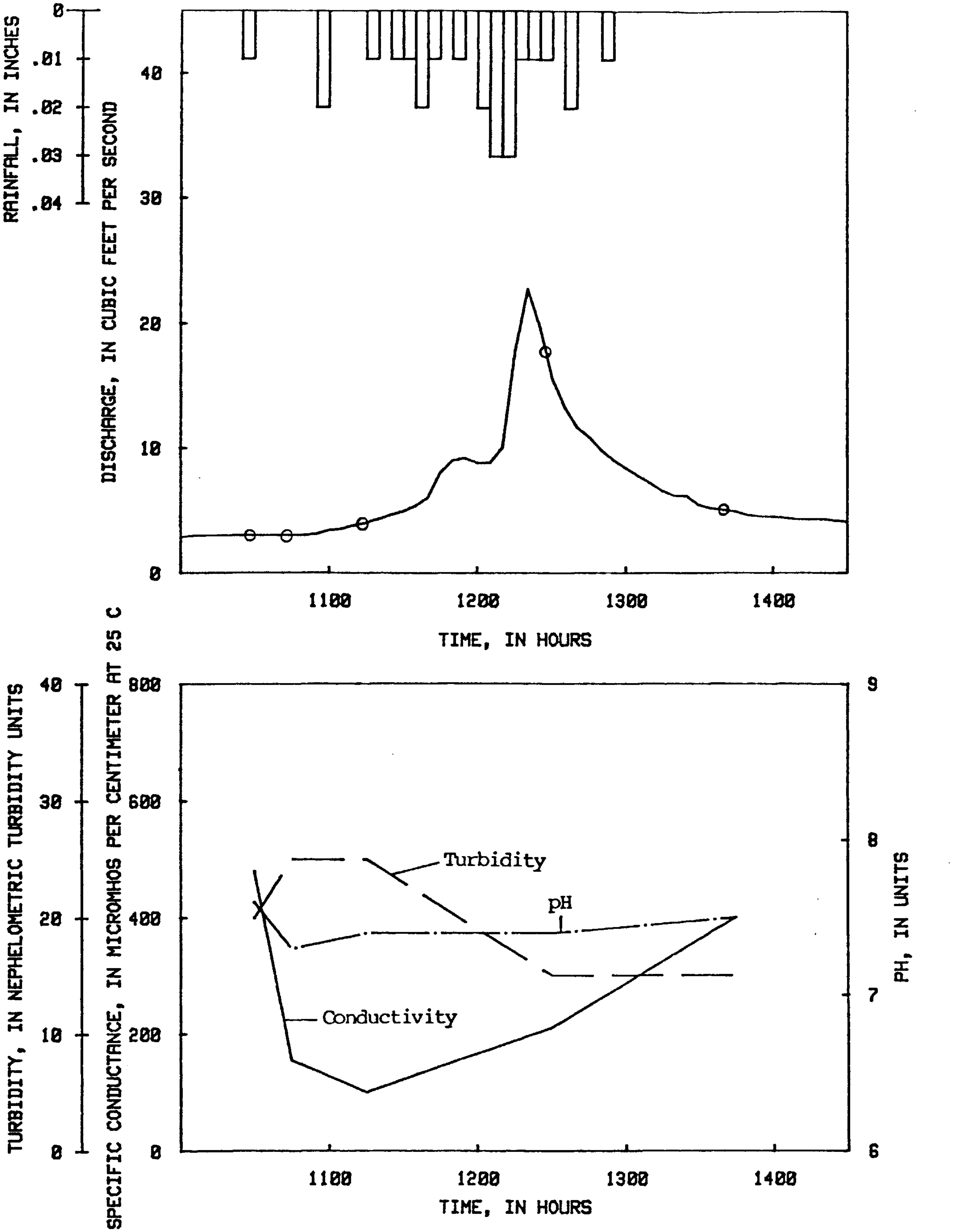



Figure 11.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of May 16, 1978.

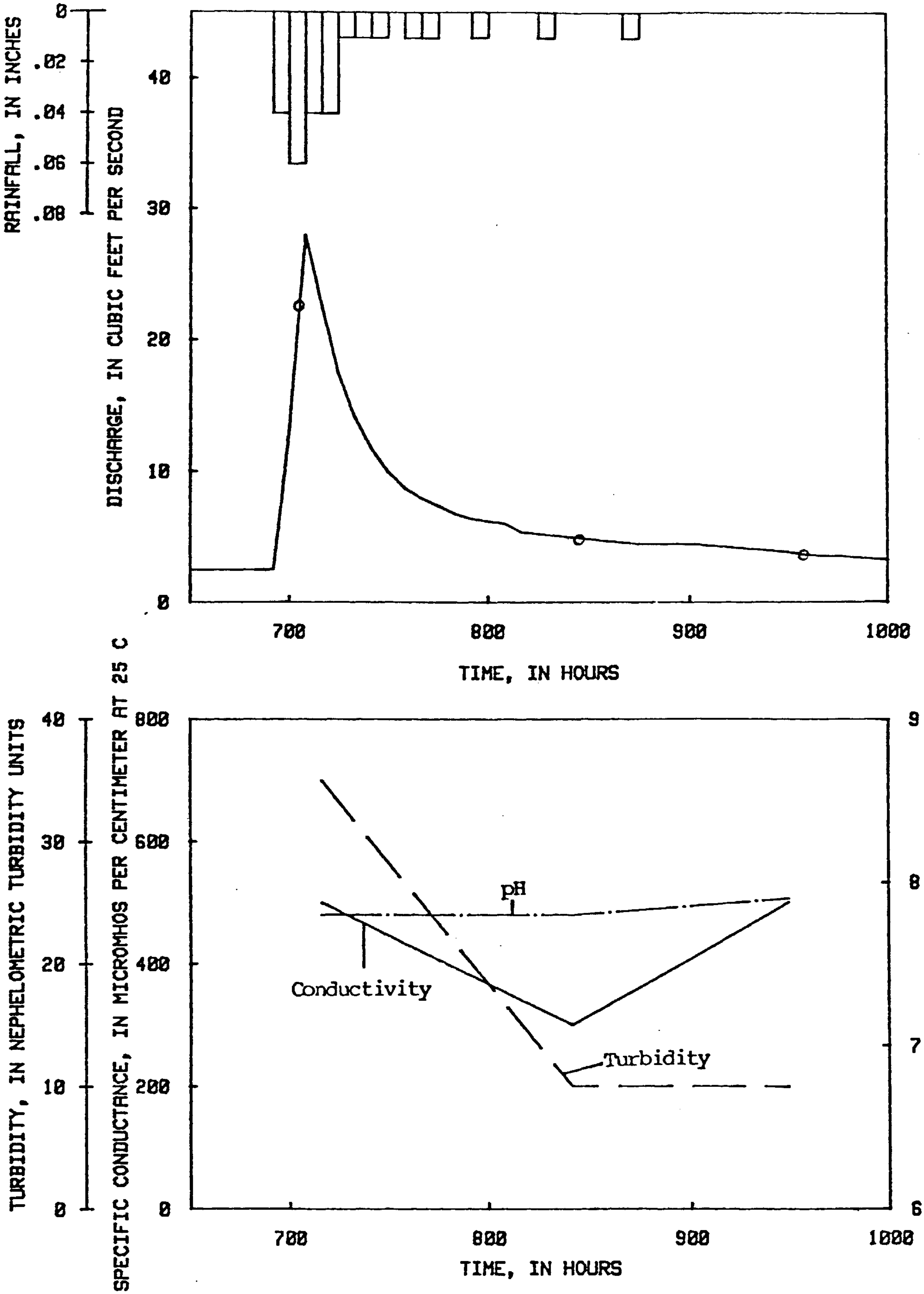



Figure 12.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of June 7, 1978.

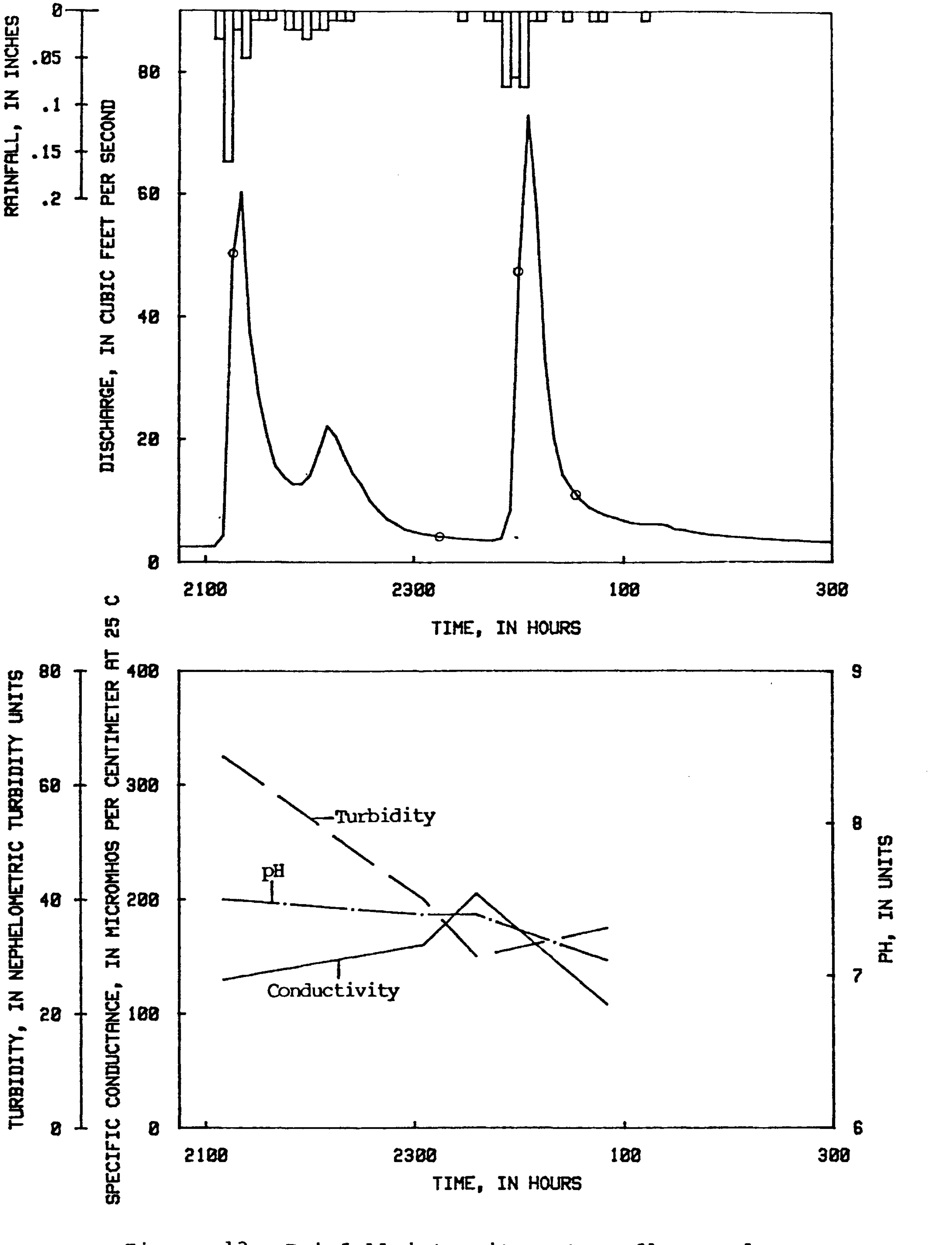



Figure 13.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of June 18, 1978.

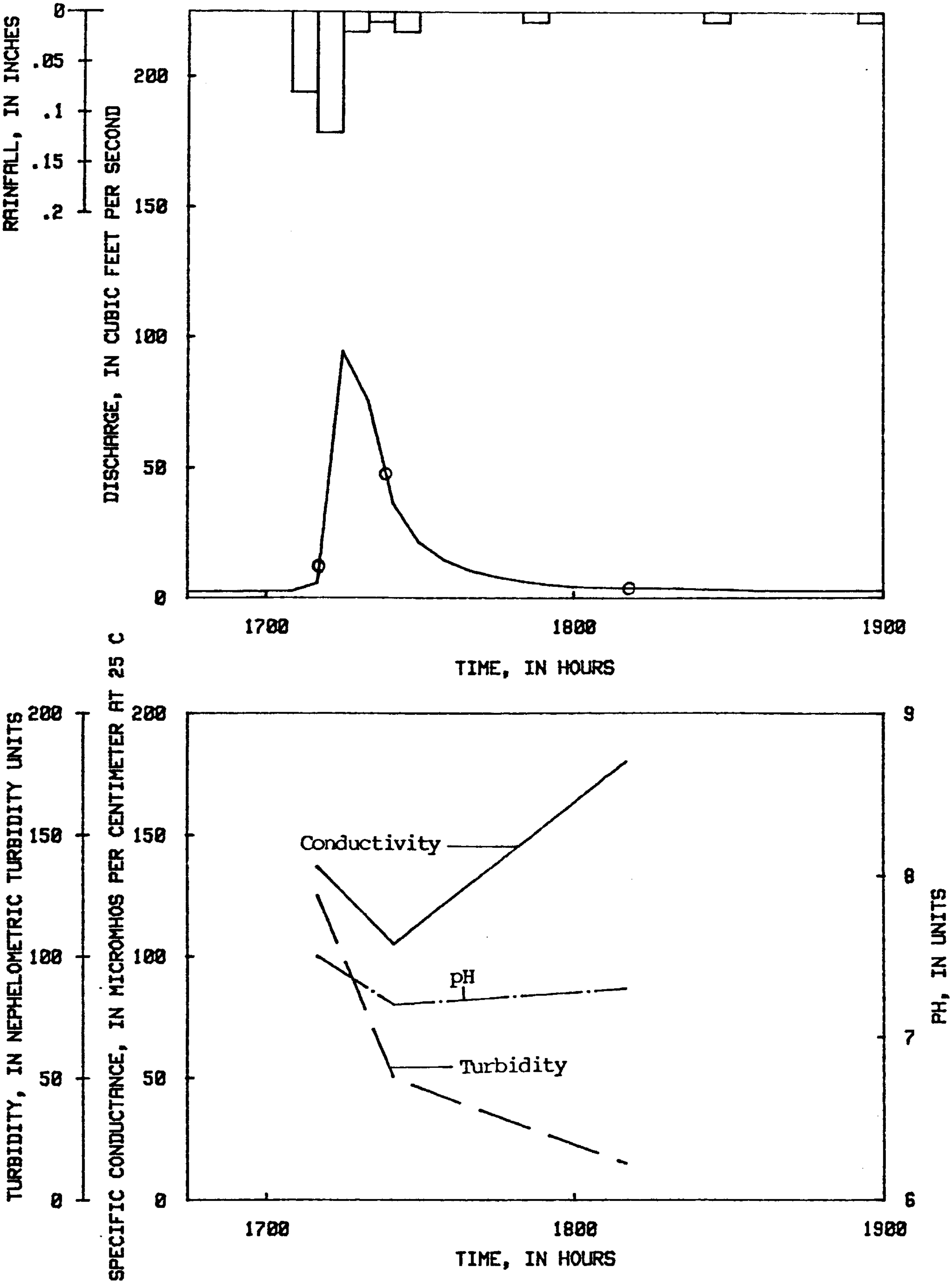



Figure 14.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of July 23, 1978.

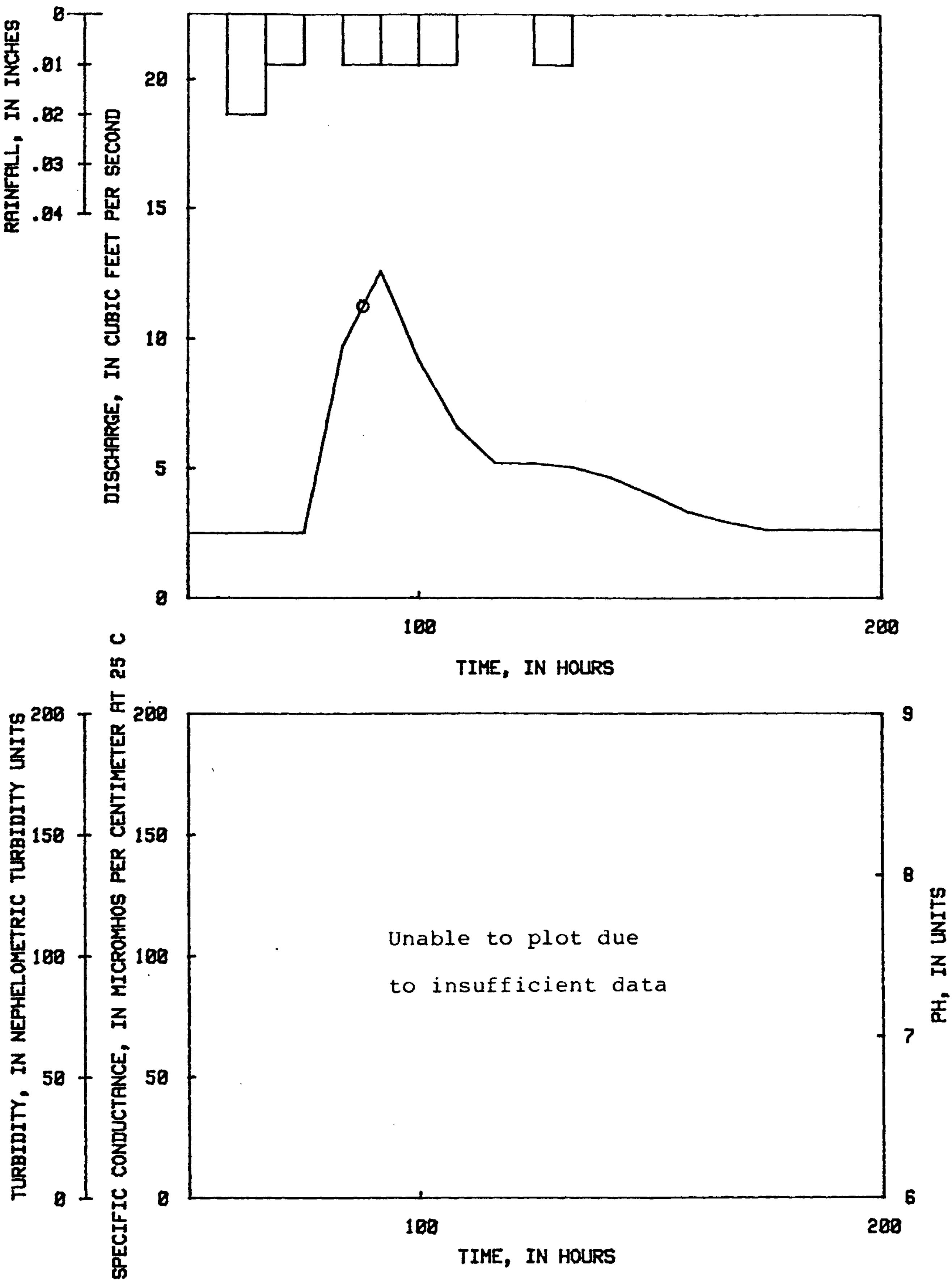



Figure 15.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of August 3, 1978.

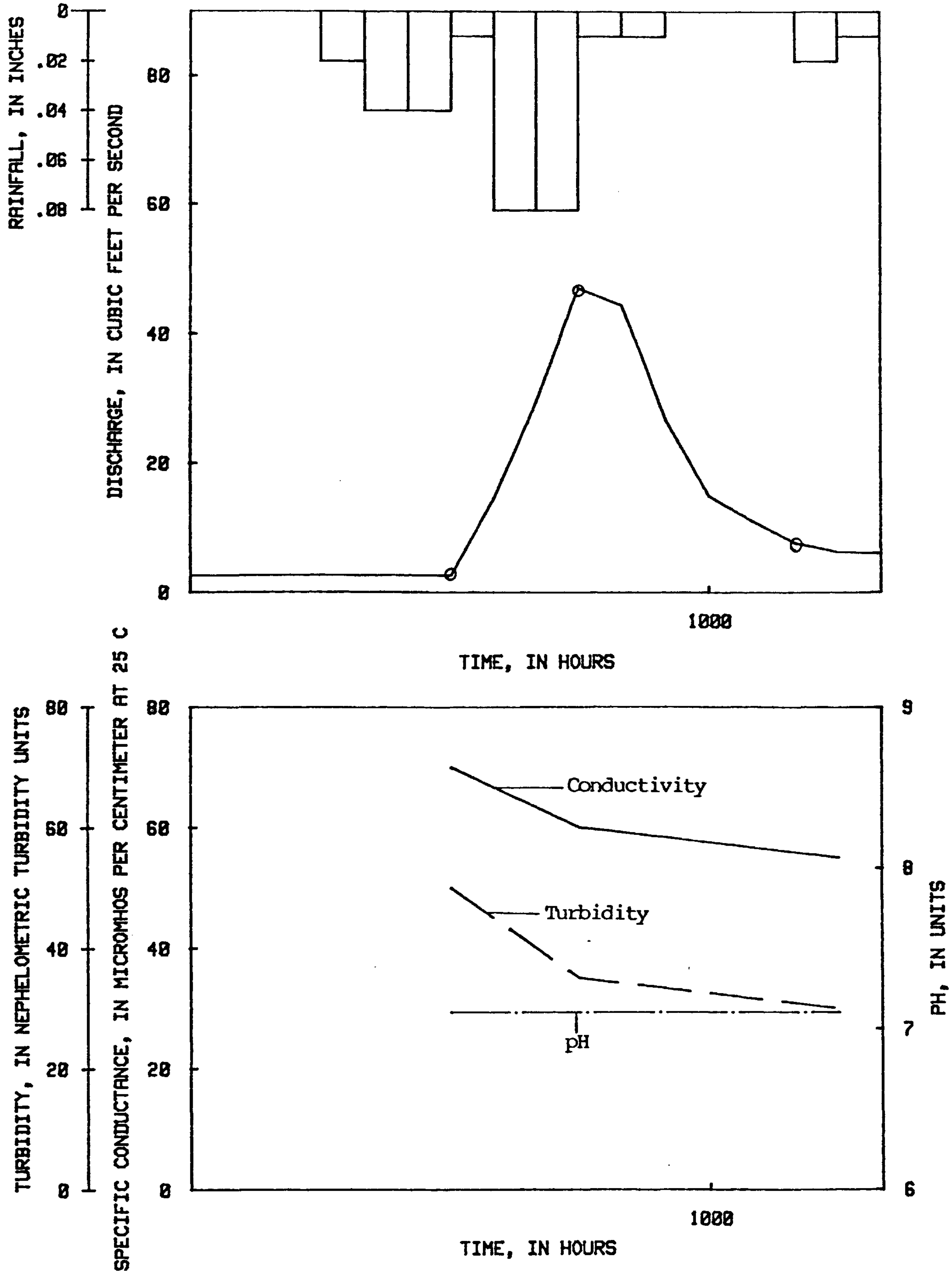



Figure 16.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of August 6, 1978.

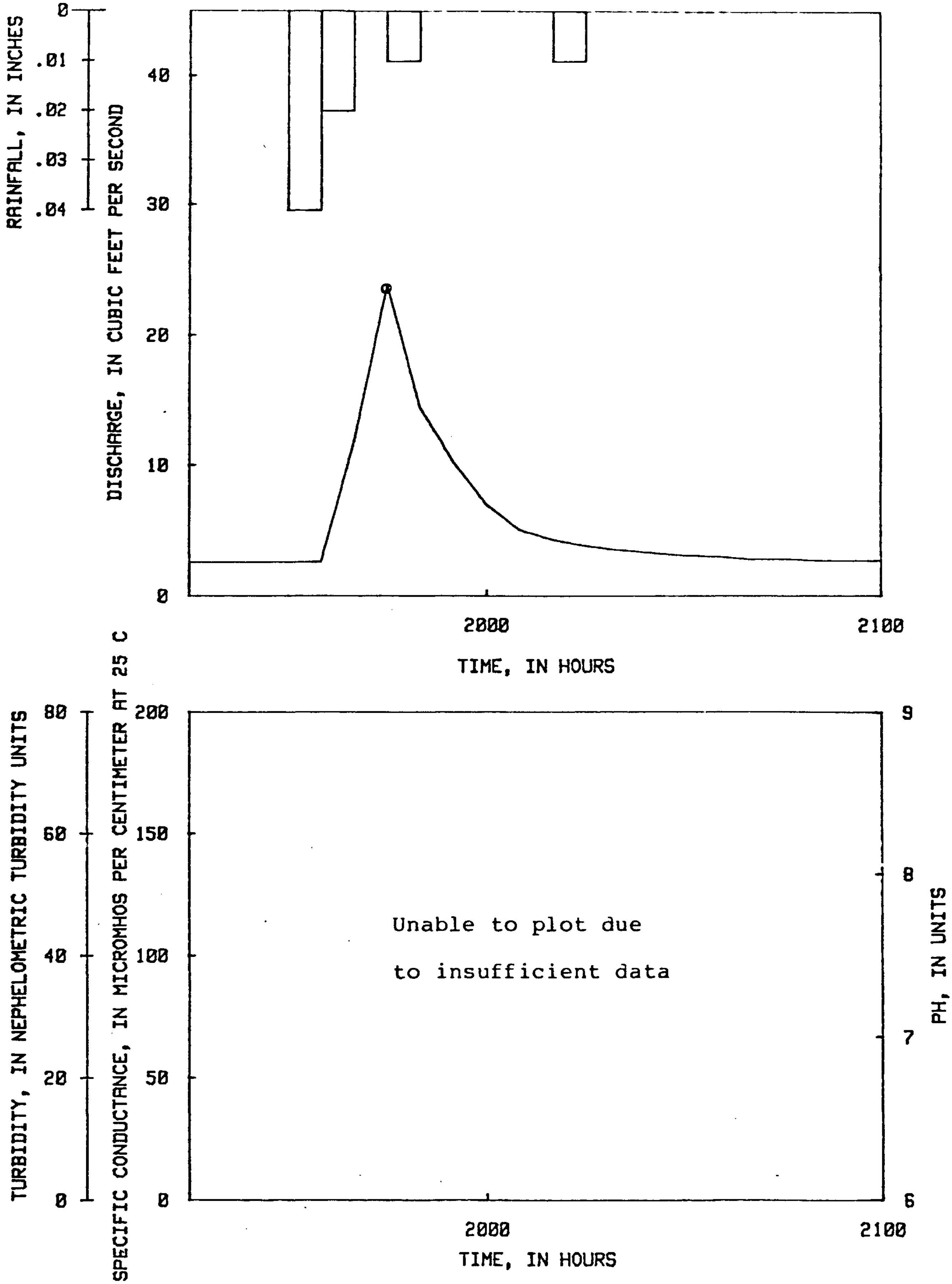



Figure 17.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of August 27, 1978.

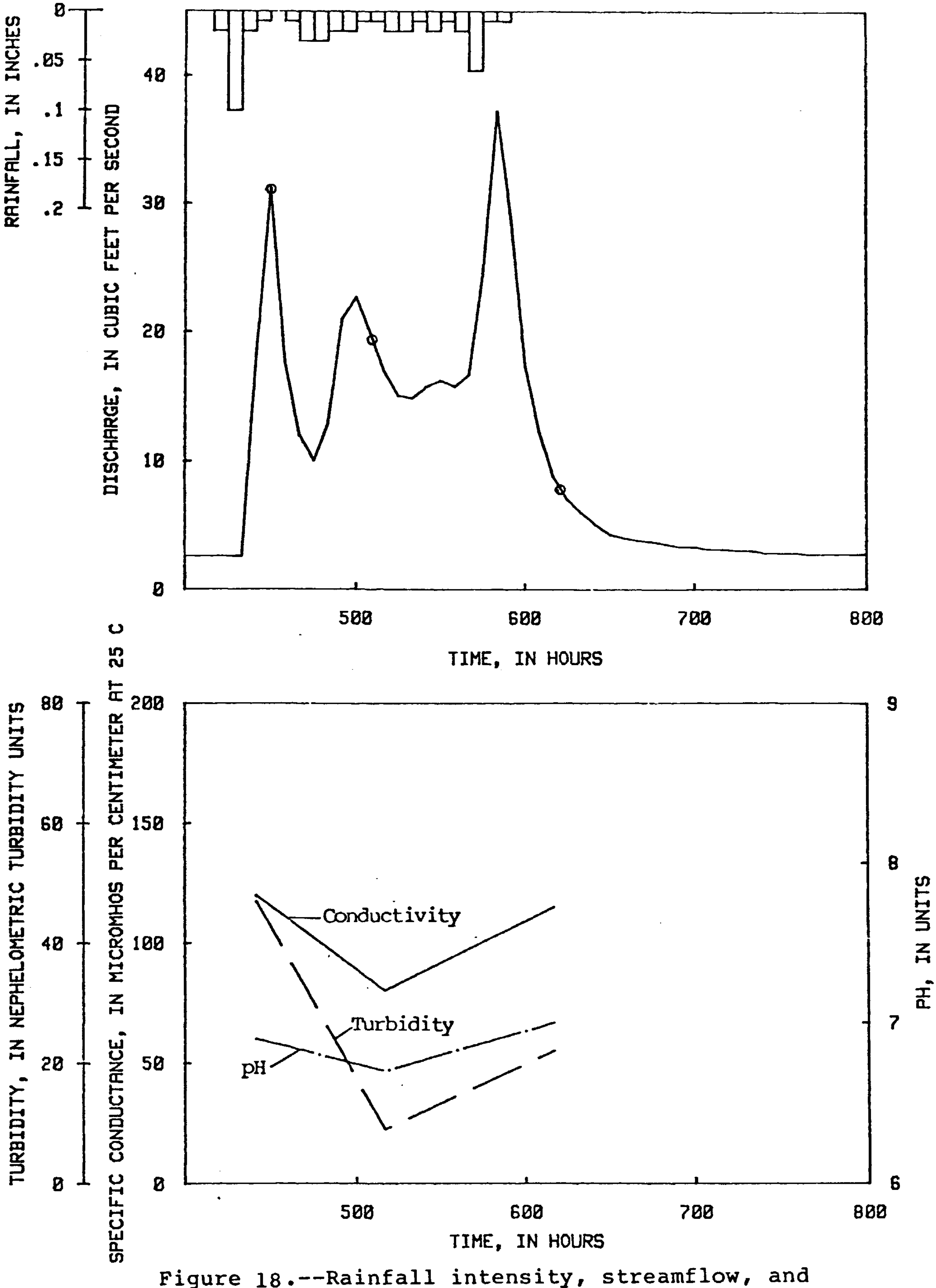



Figure 18.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of August 28, 1978.

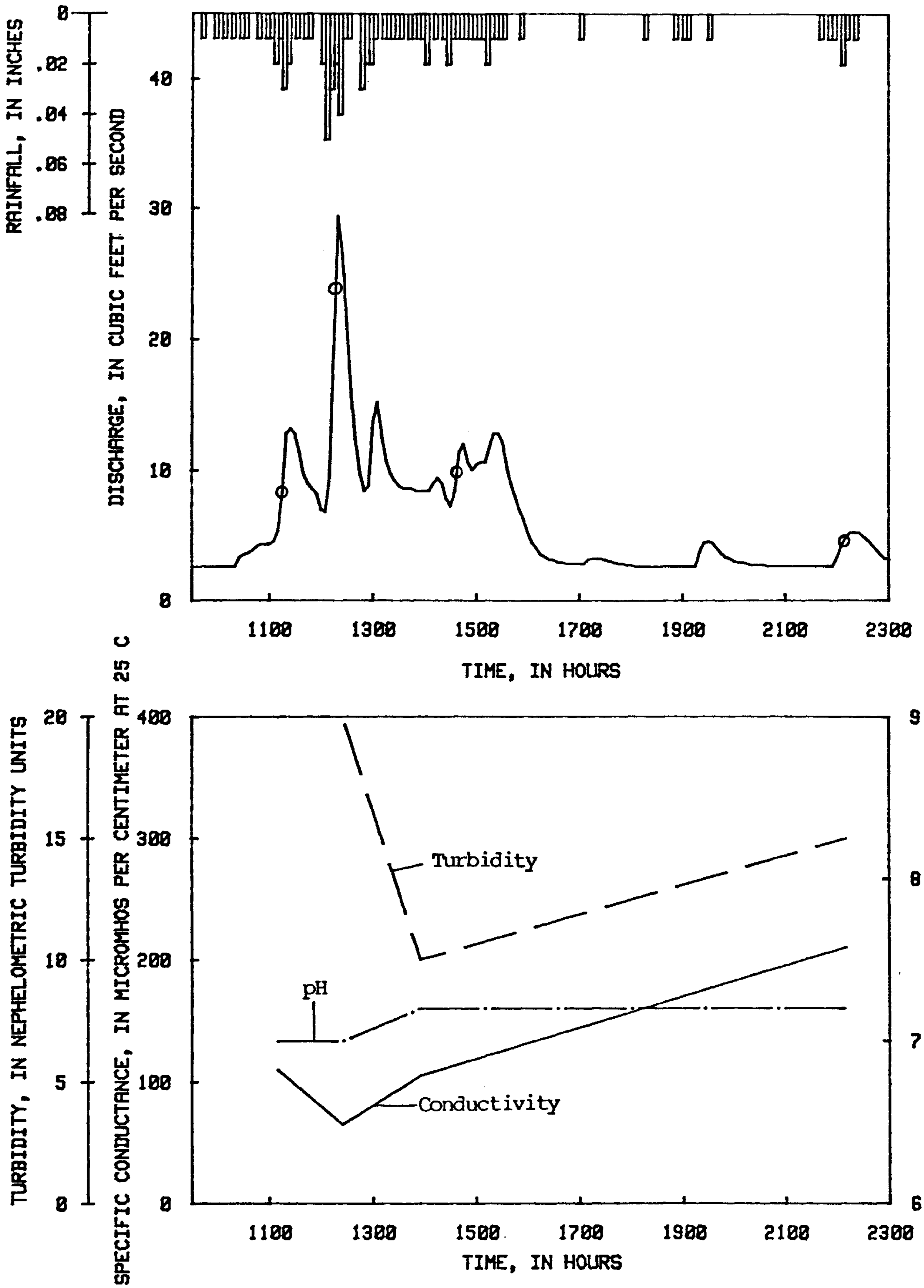



Figure 19.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of August 30, 1978.

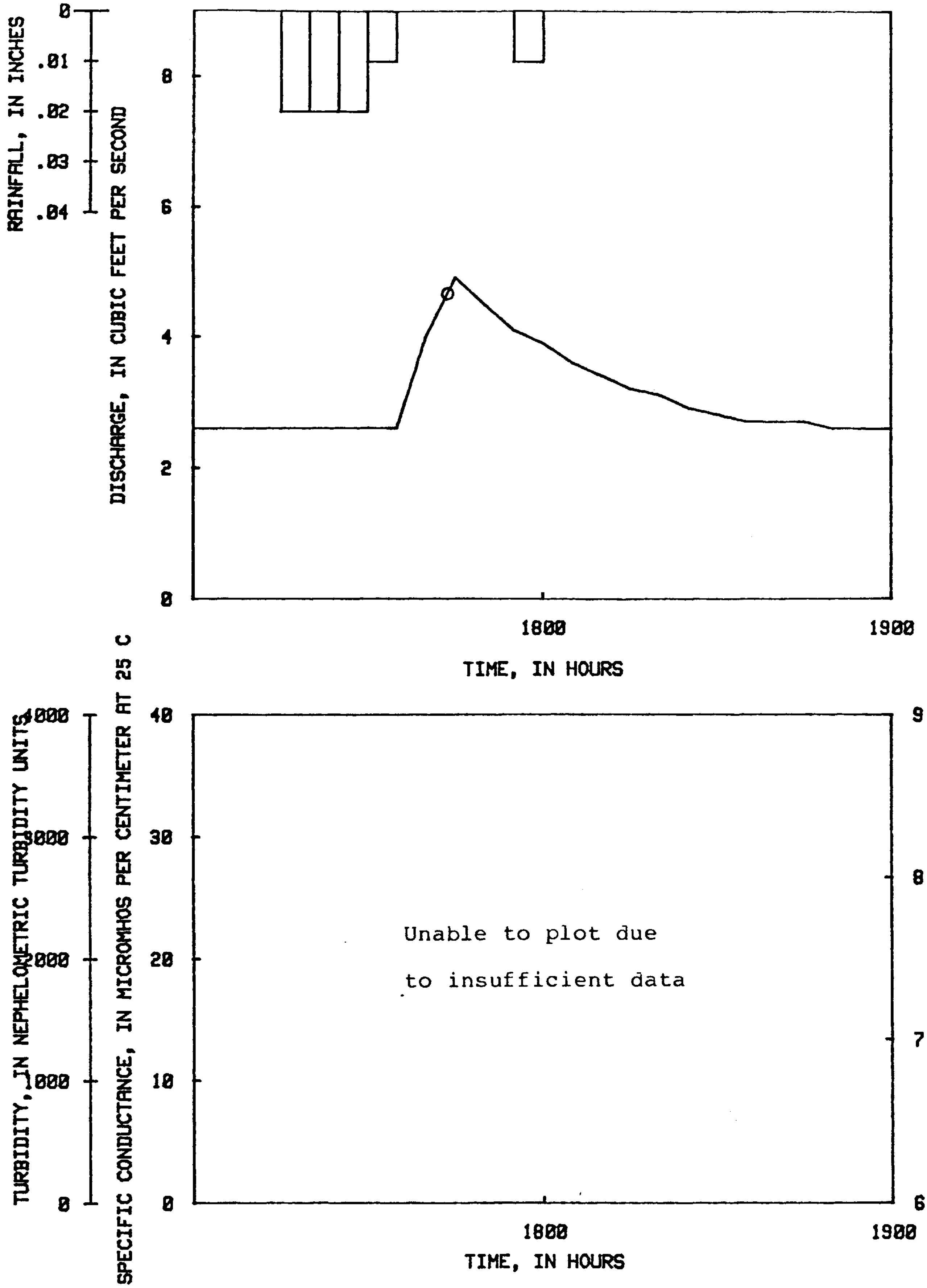



Figure 20.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of September 30, 1978.

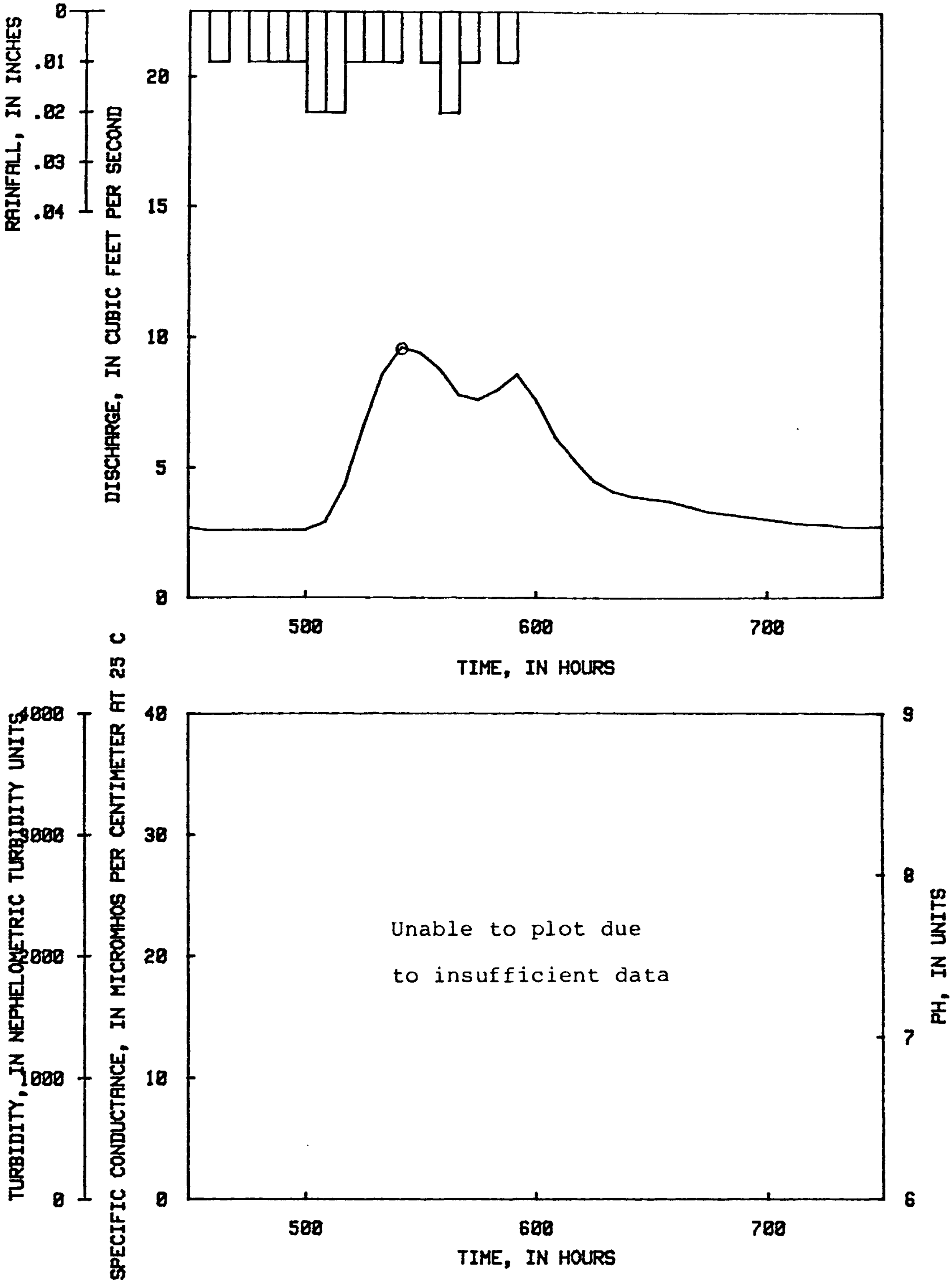
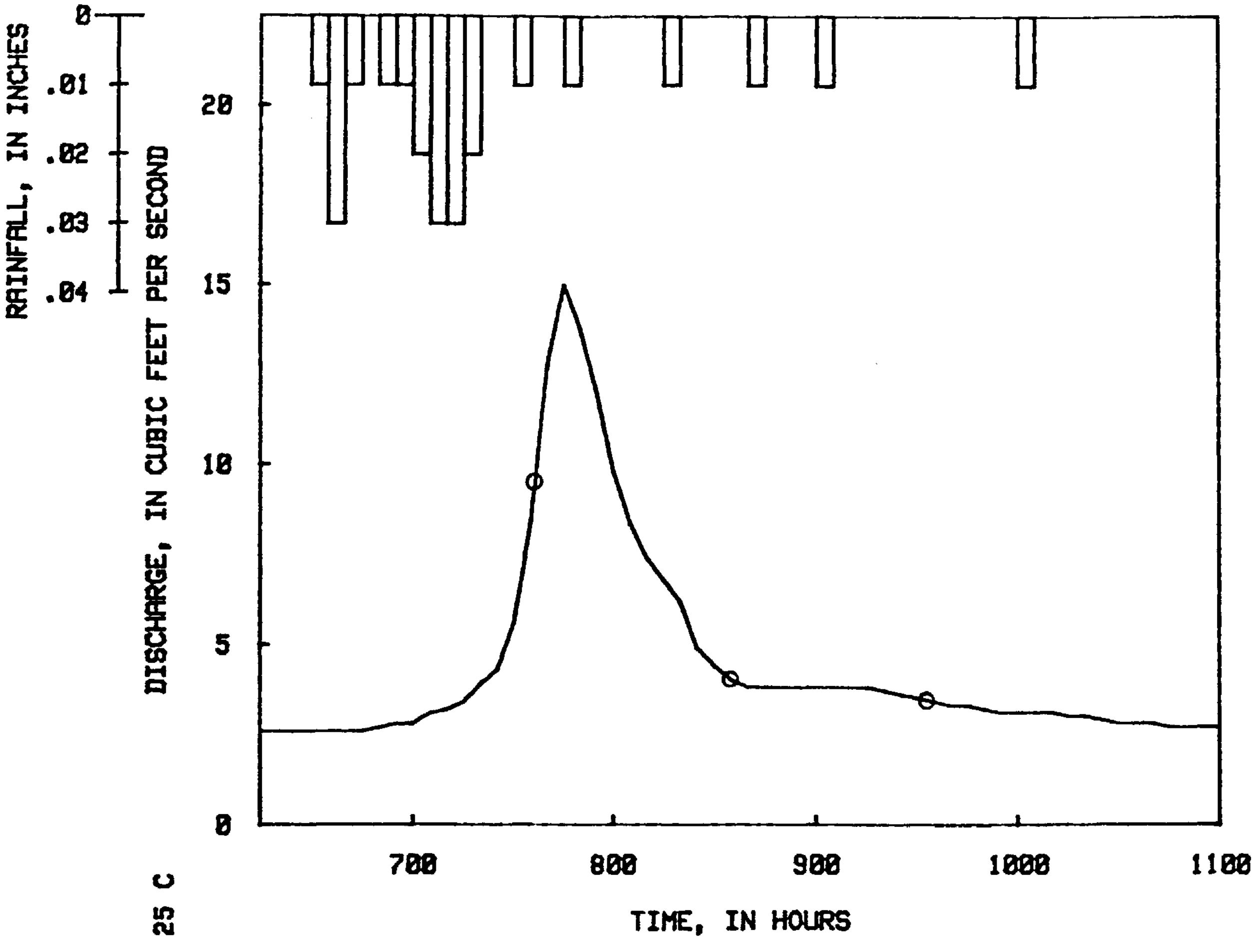



Figure 21.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of November 17, 1978.



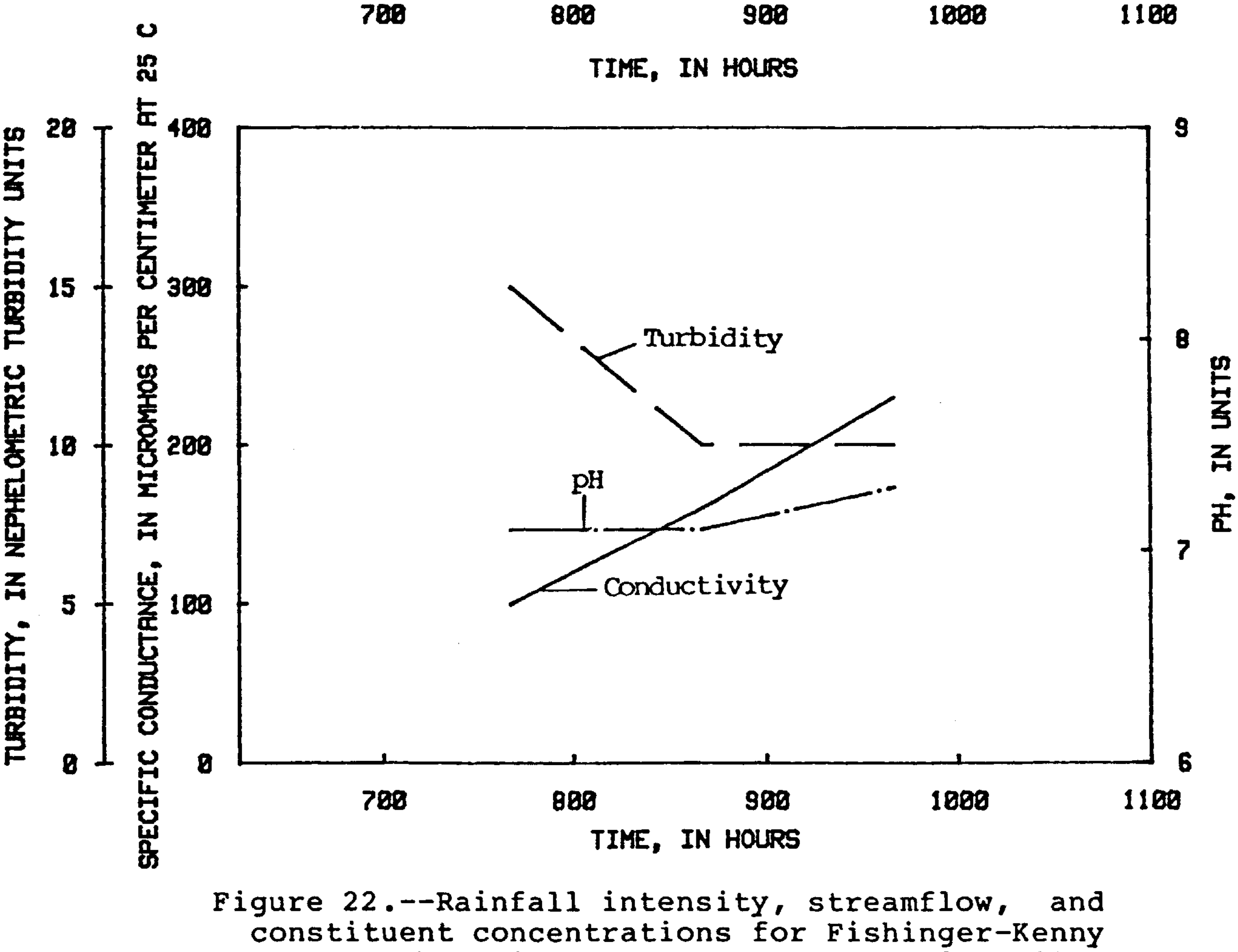




Figure 22.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of November 23, 1978.

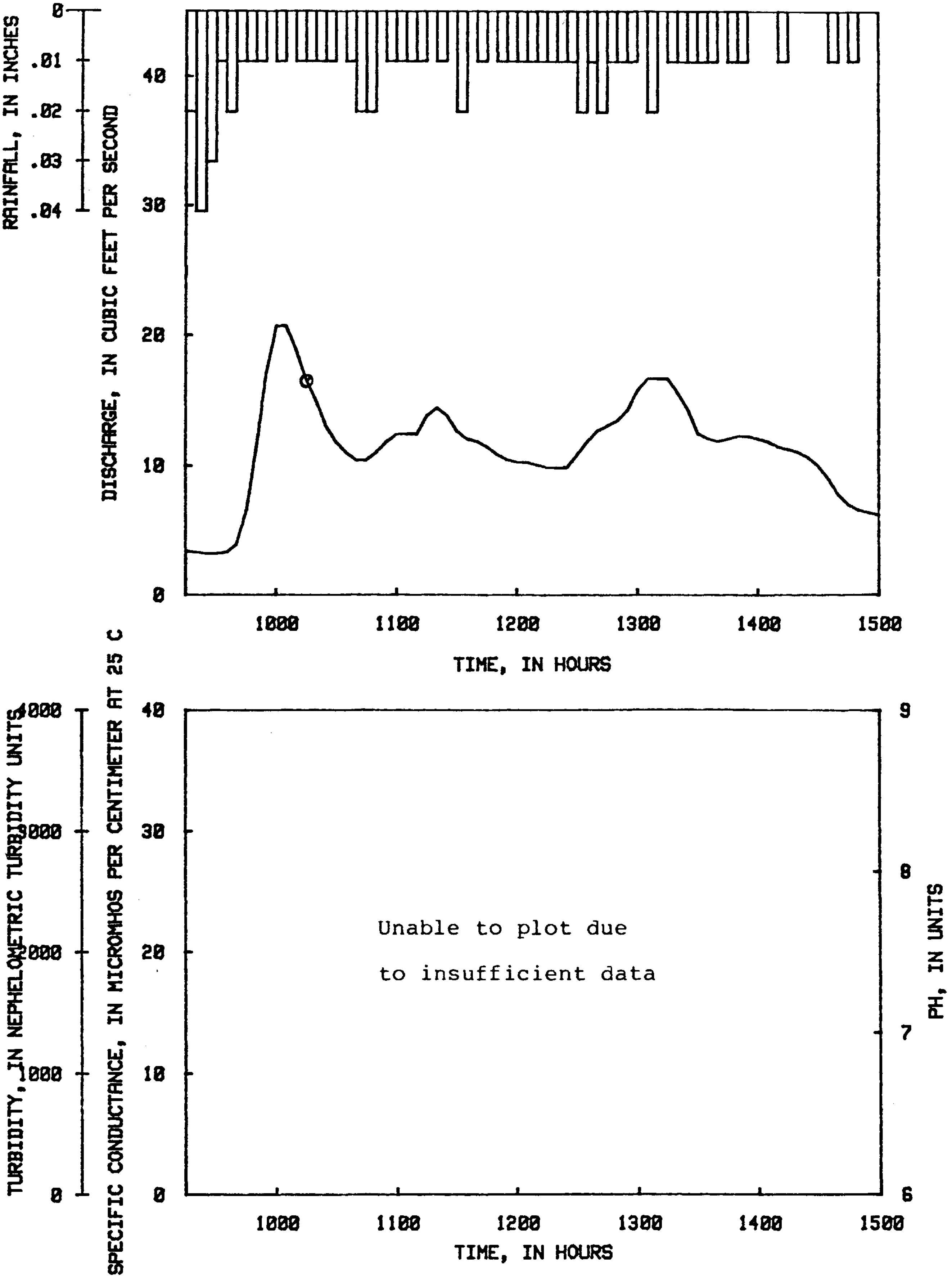



Figure 23.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of December 8, 1978.

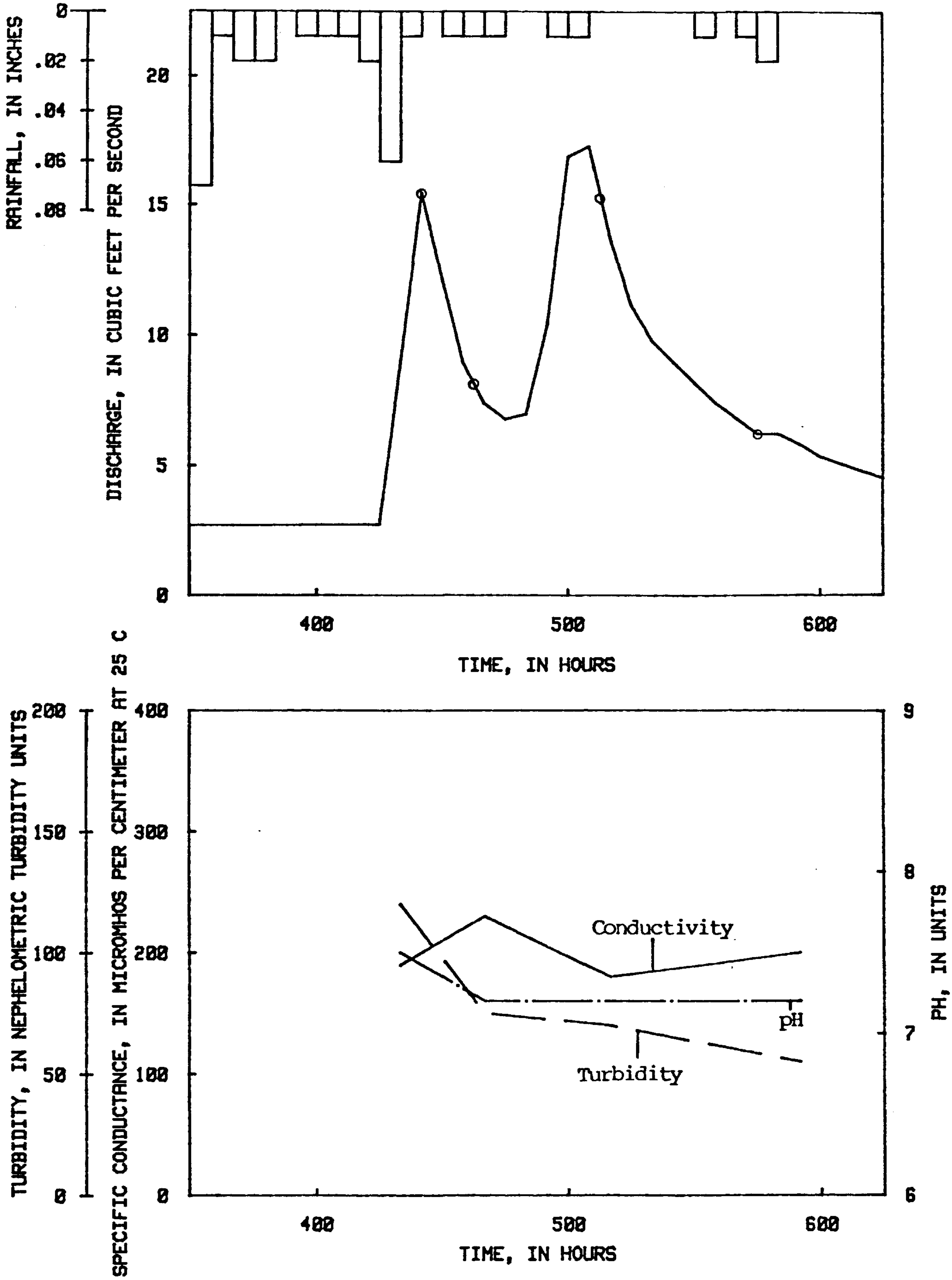



Figure 24.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of March 31, 1979.

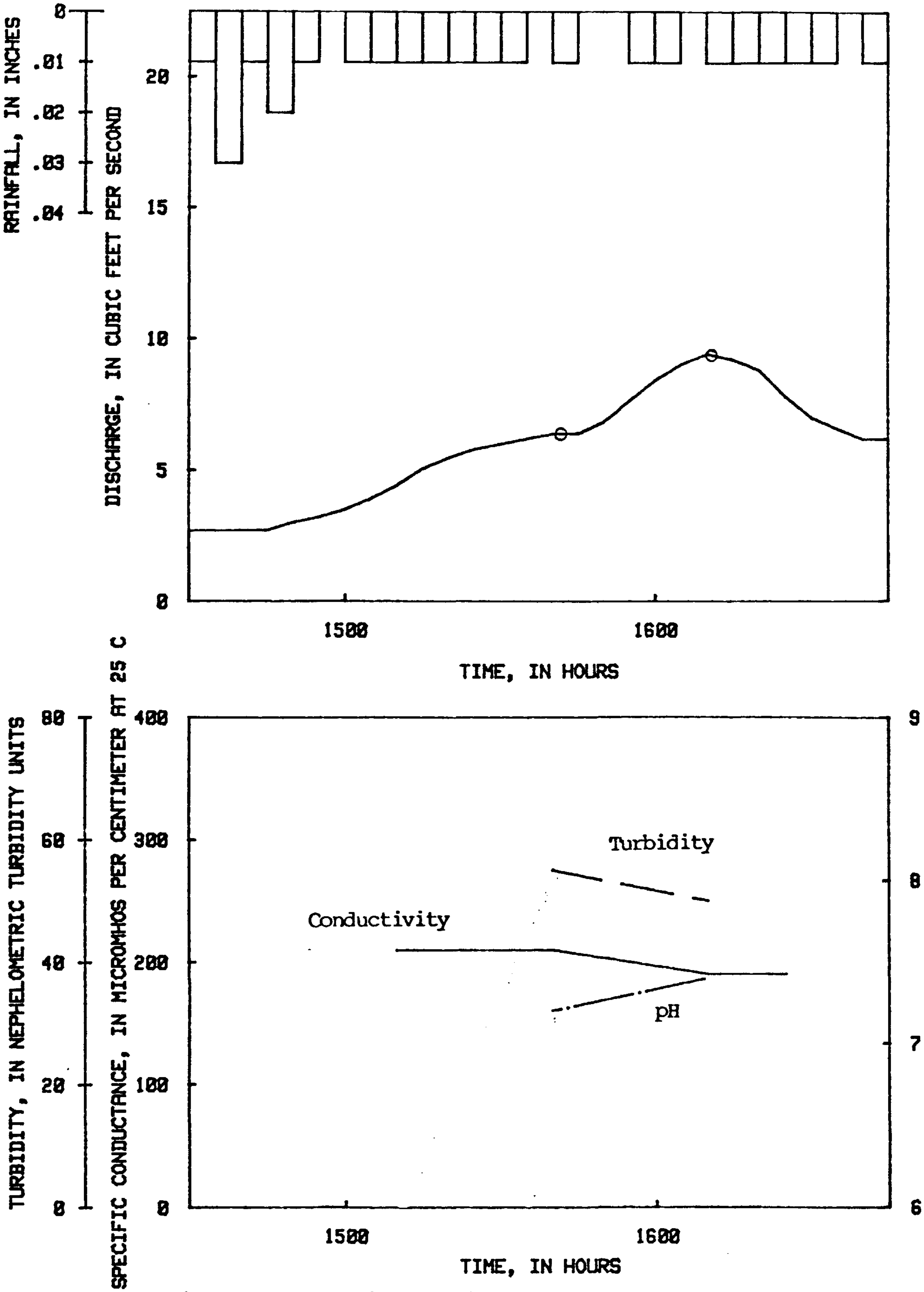


Figure 25.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of April 1, 1979.

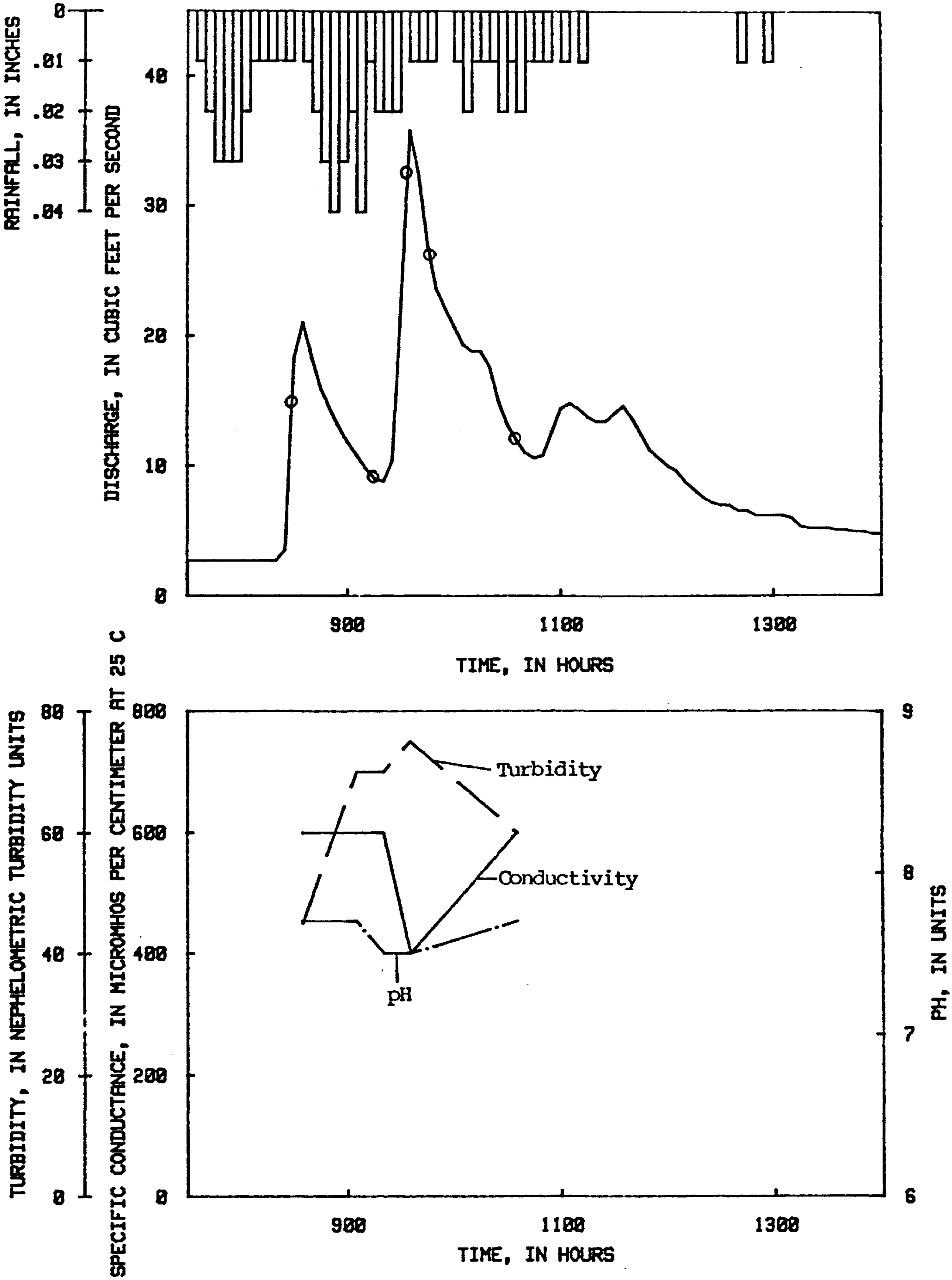



Figure 26.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of April 4, 1979.

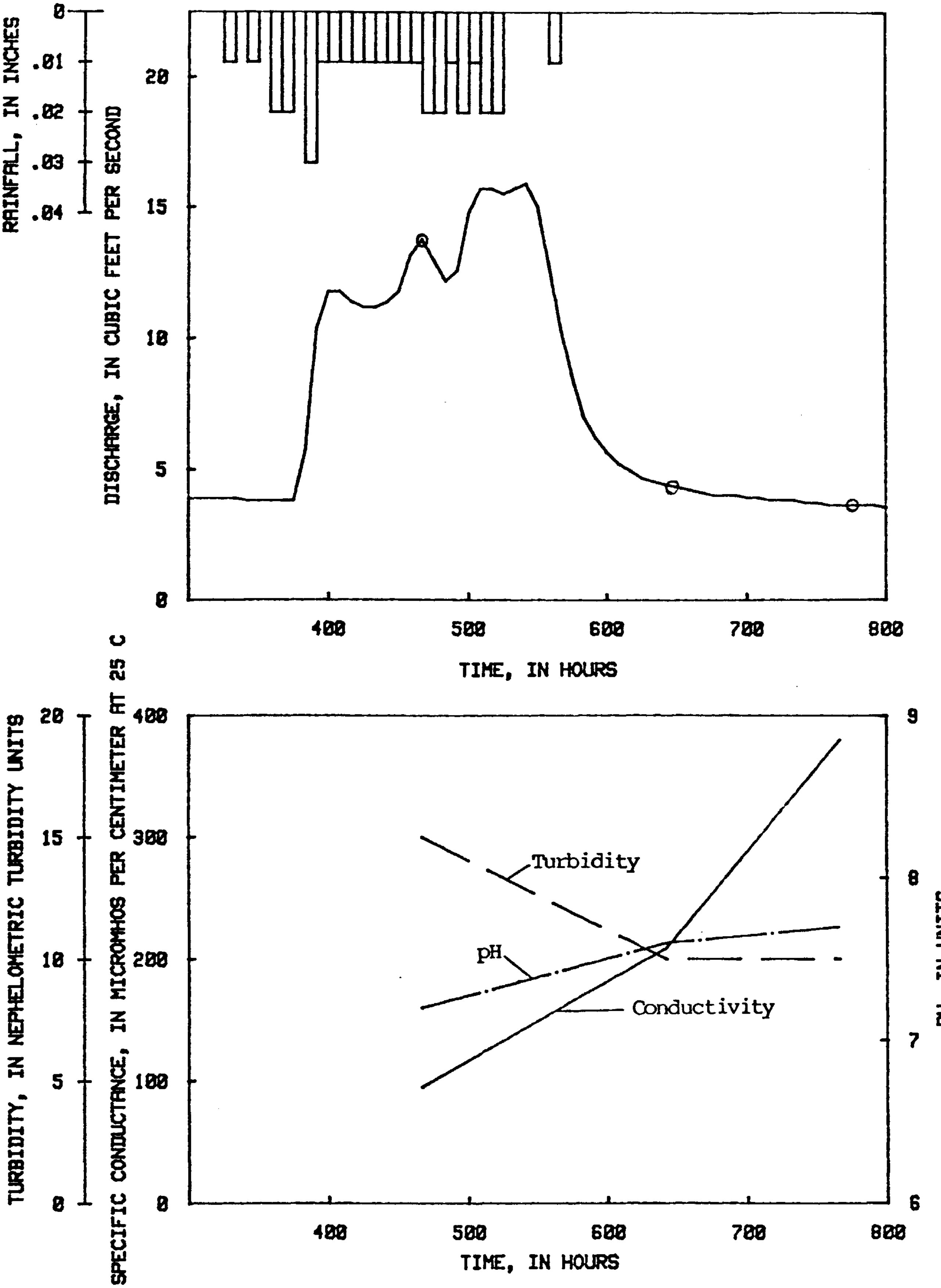



Figure 27.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of June 6, 1979.

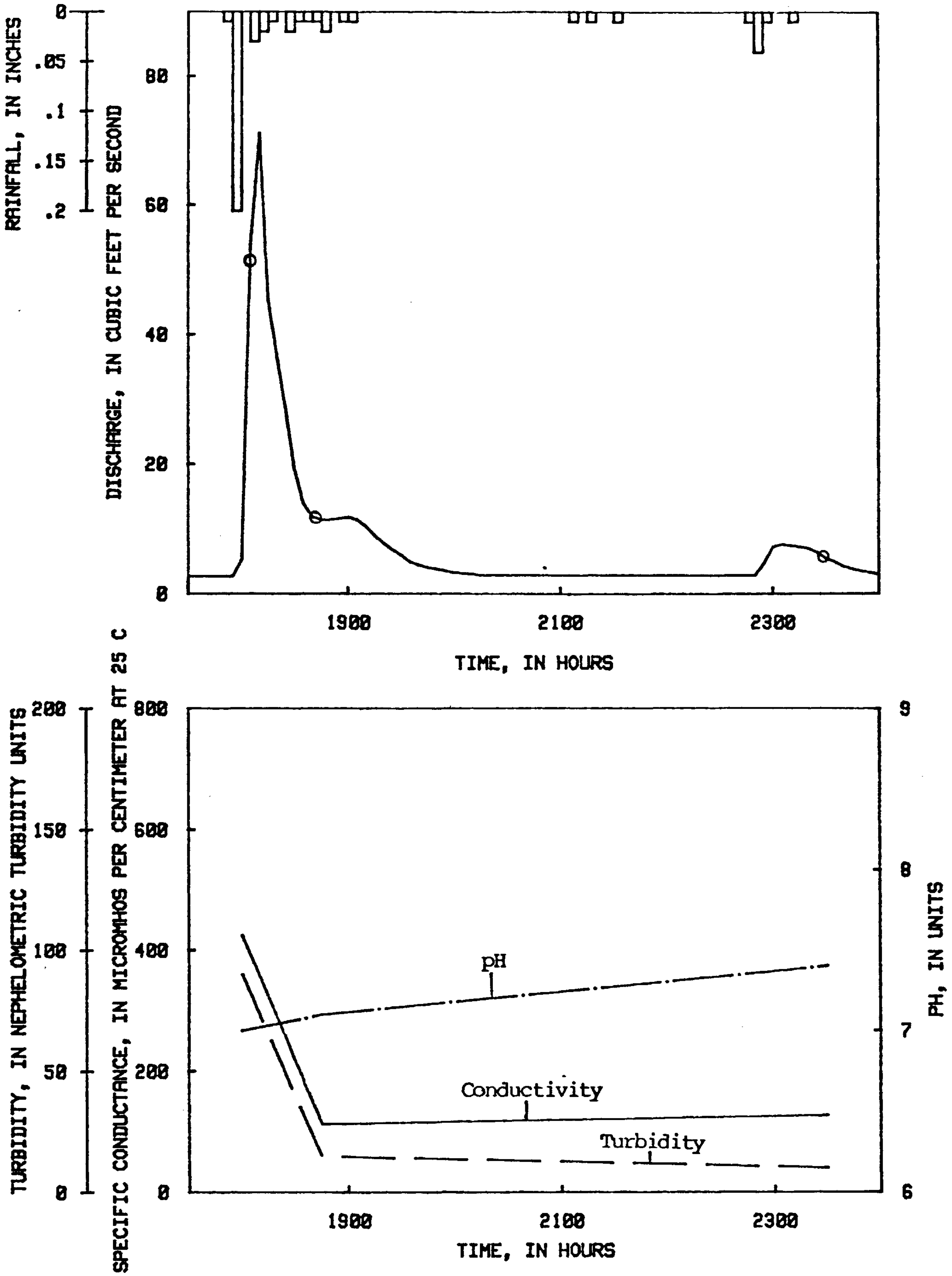



Figure 28.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of August 1, 1979.

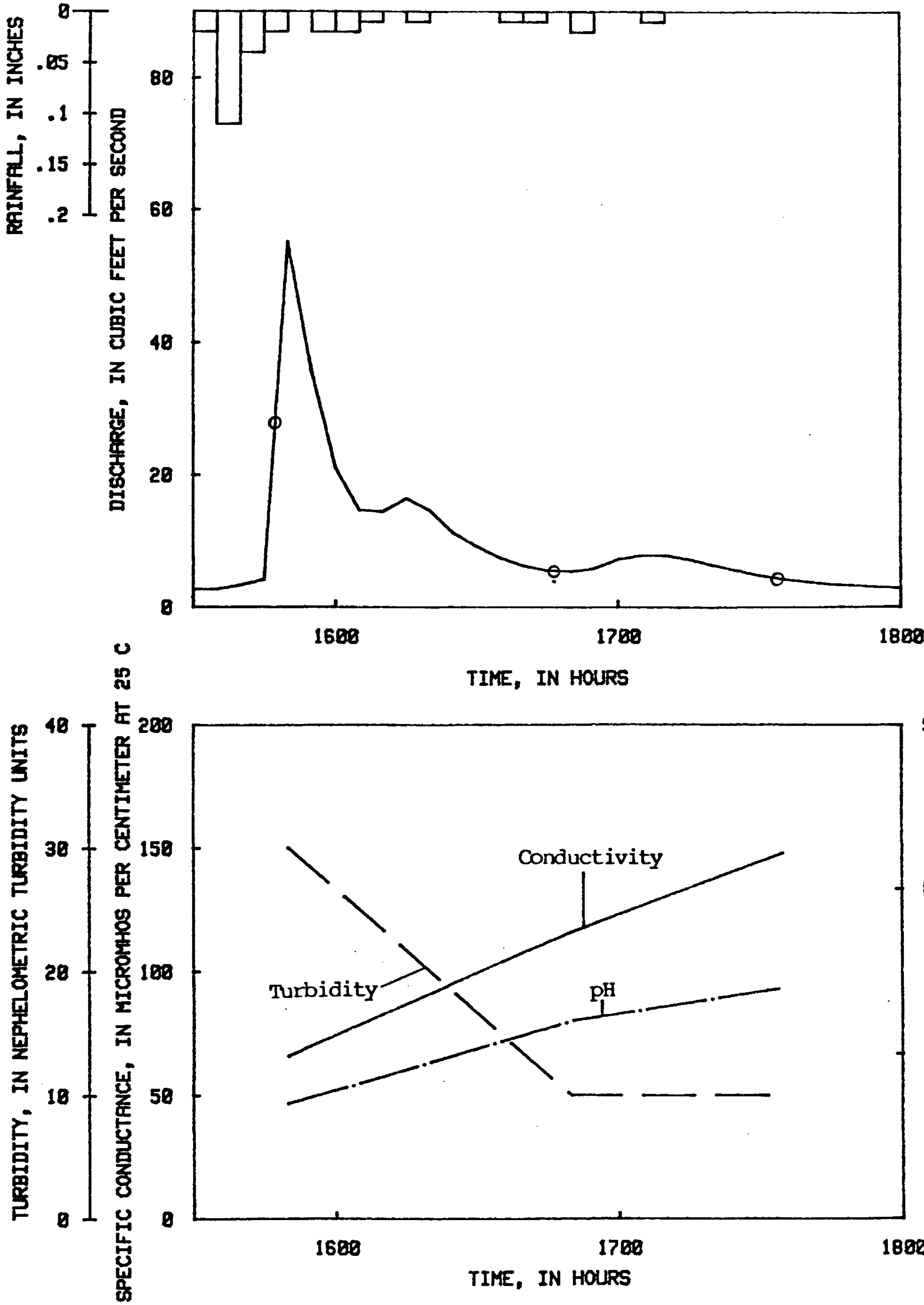



Figure 29.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of August 5, 1979.

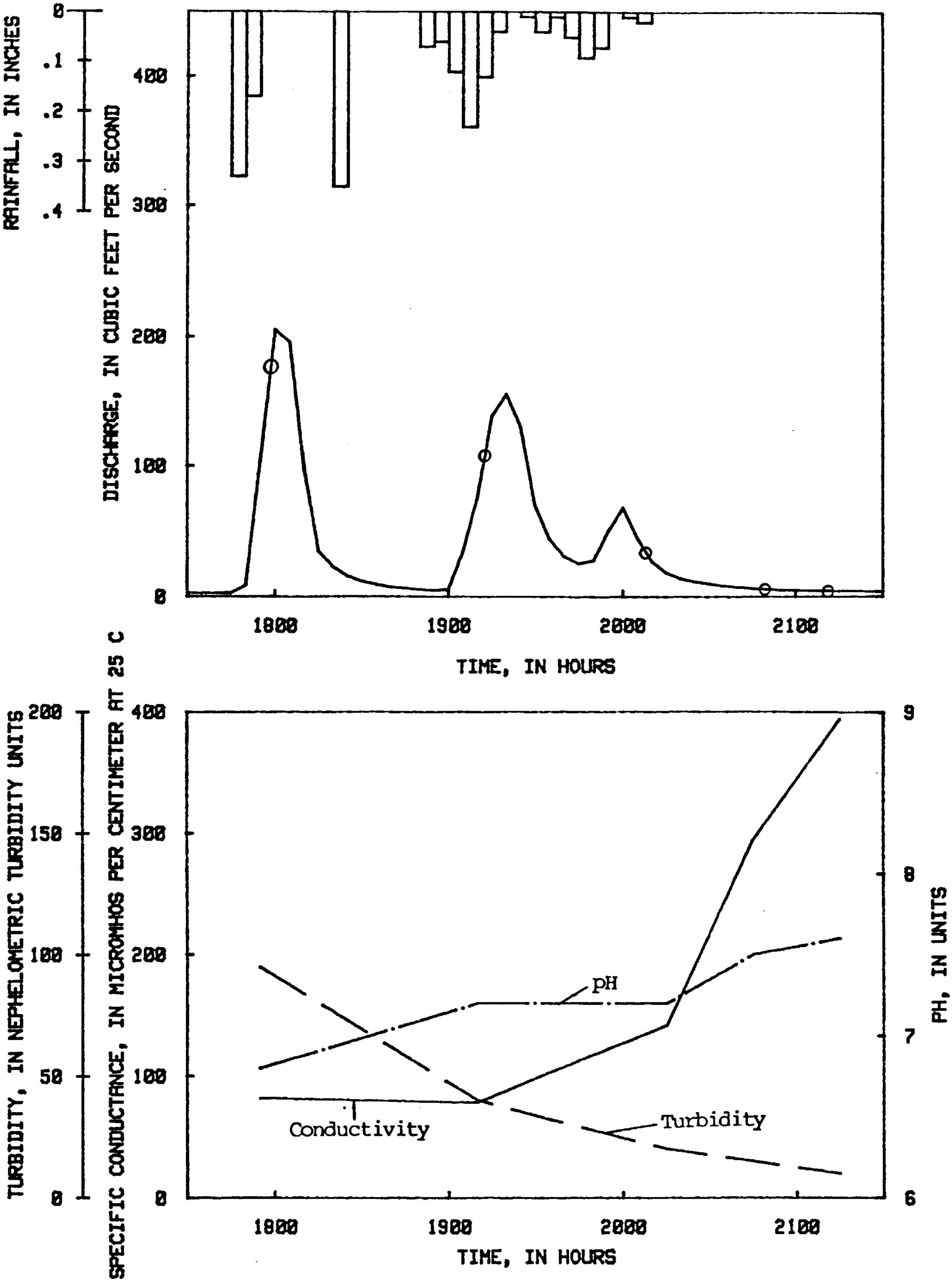



Figure 30.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of August 20, 1979.

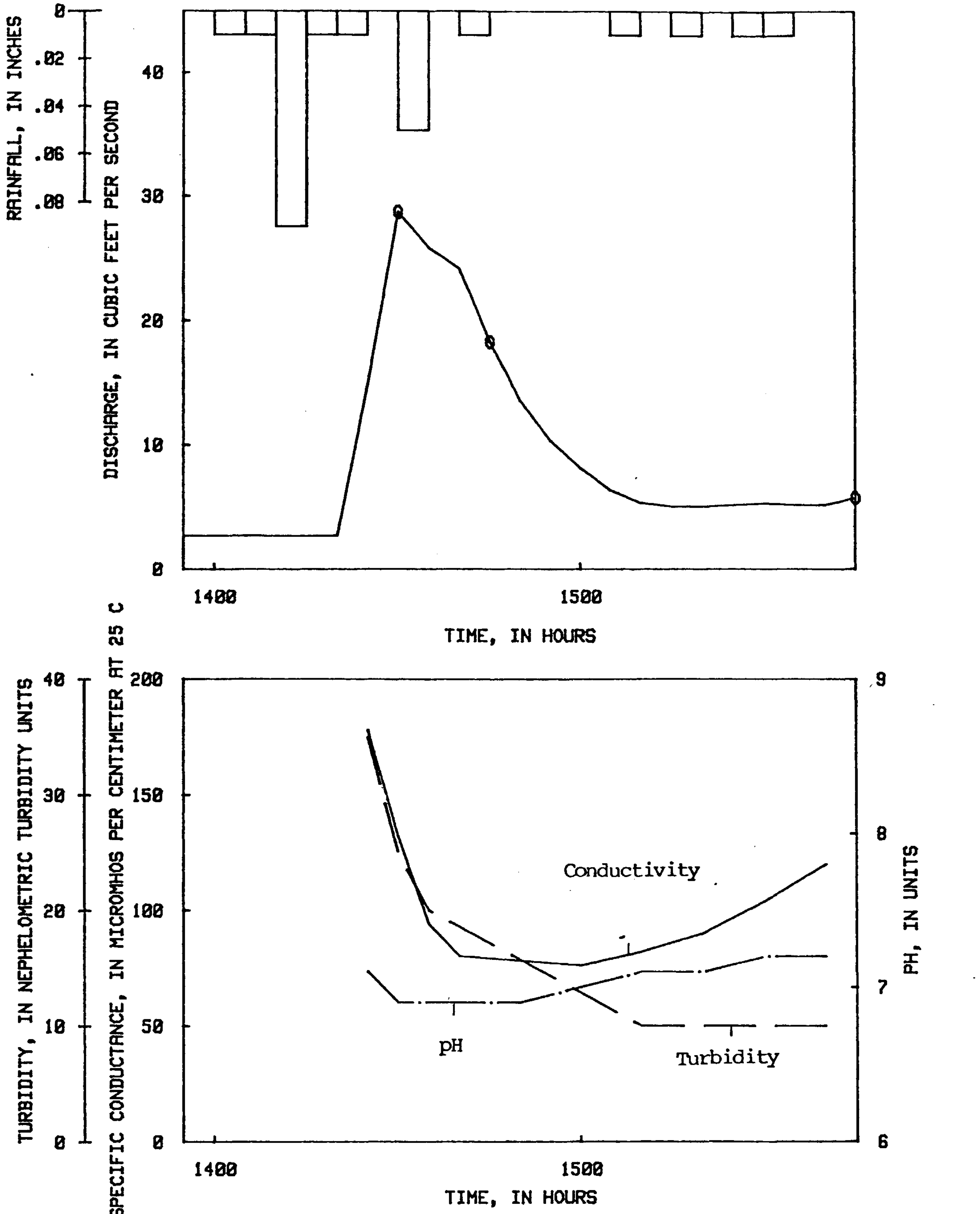



Figure 31.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of August 28, 1979

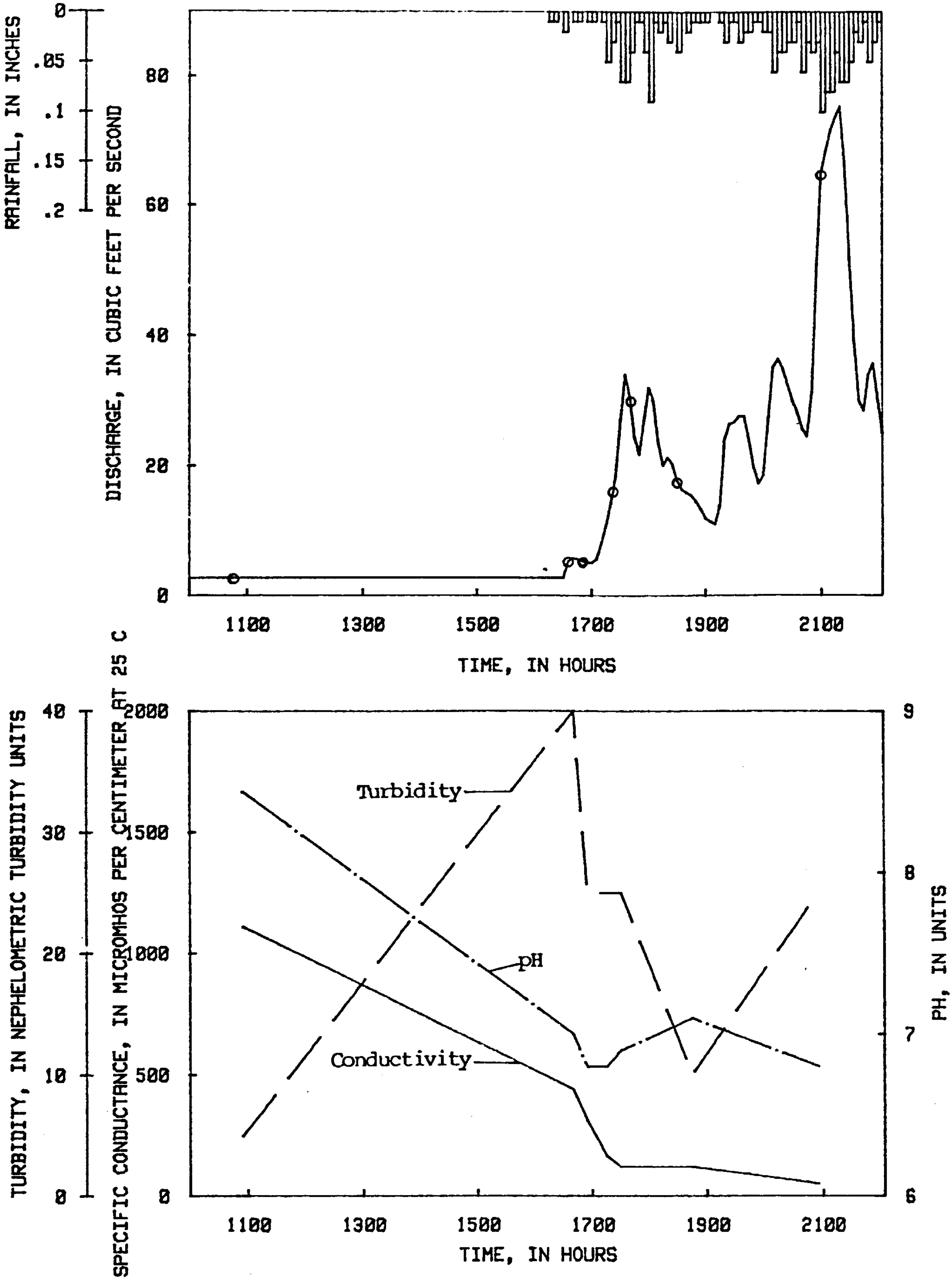



Figure 32.--Rainfall intensity, streamflow, and constituent concentrations for Fishinger-Kenny Road Creek during storm of September 13, 1979.

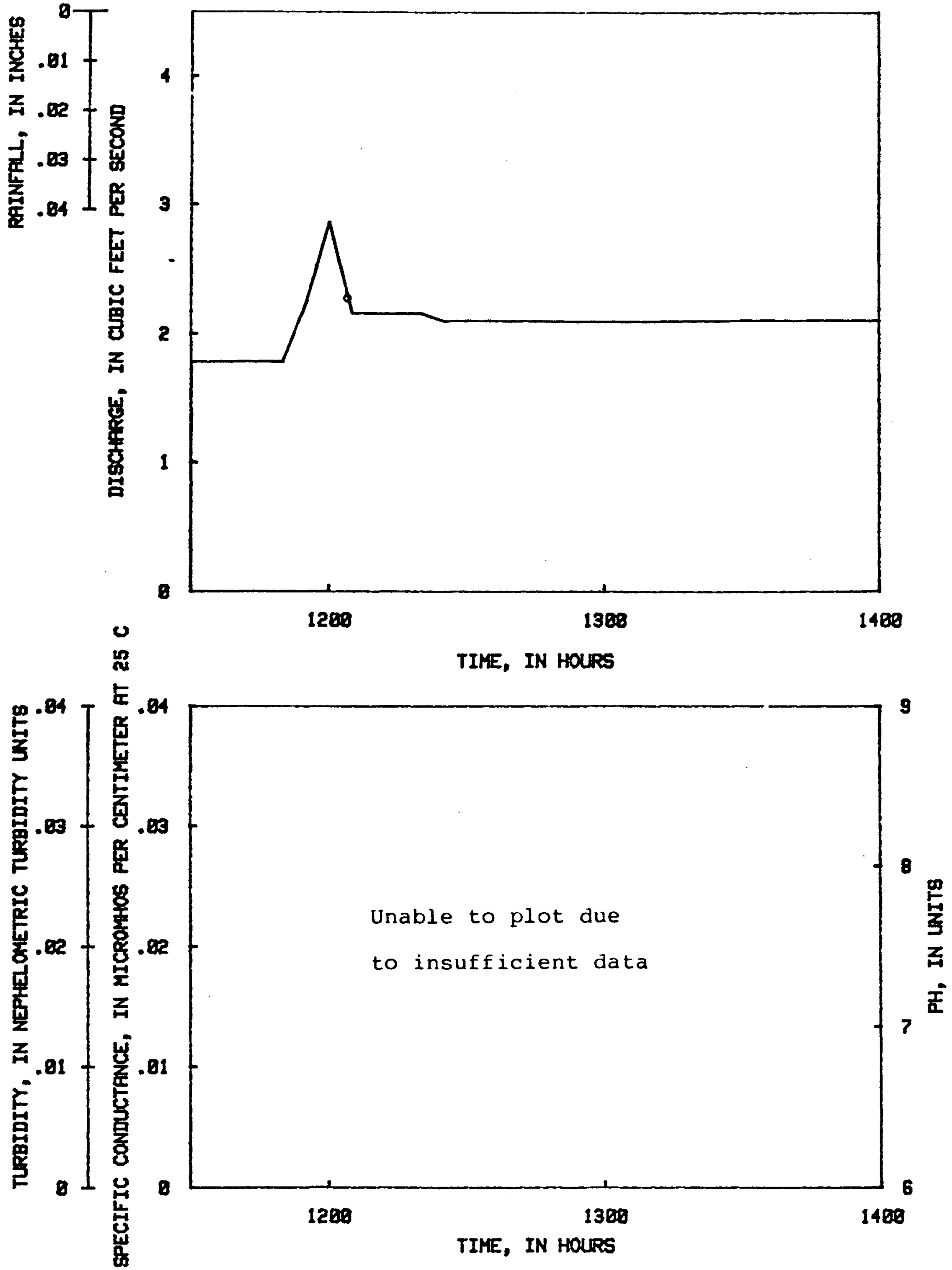



Figure 33.--Rainfall intensity, streamflow, and constituent concentrations for Norman Ditch during storm of January 25, 1978.

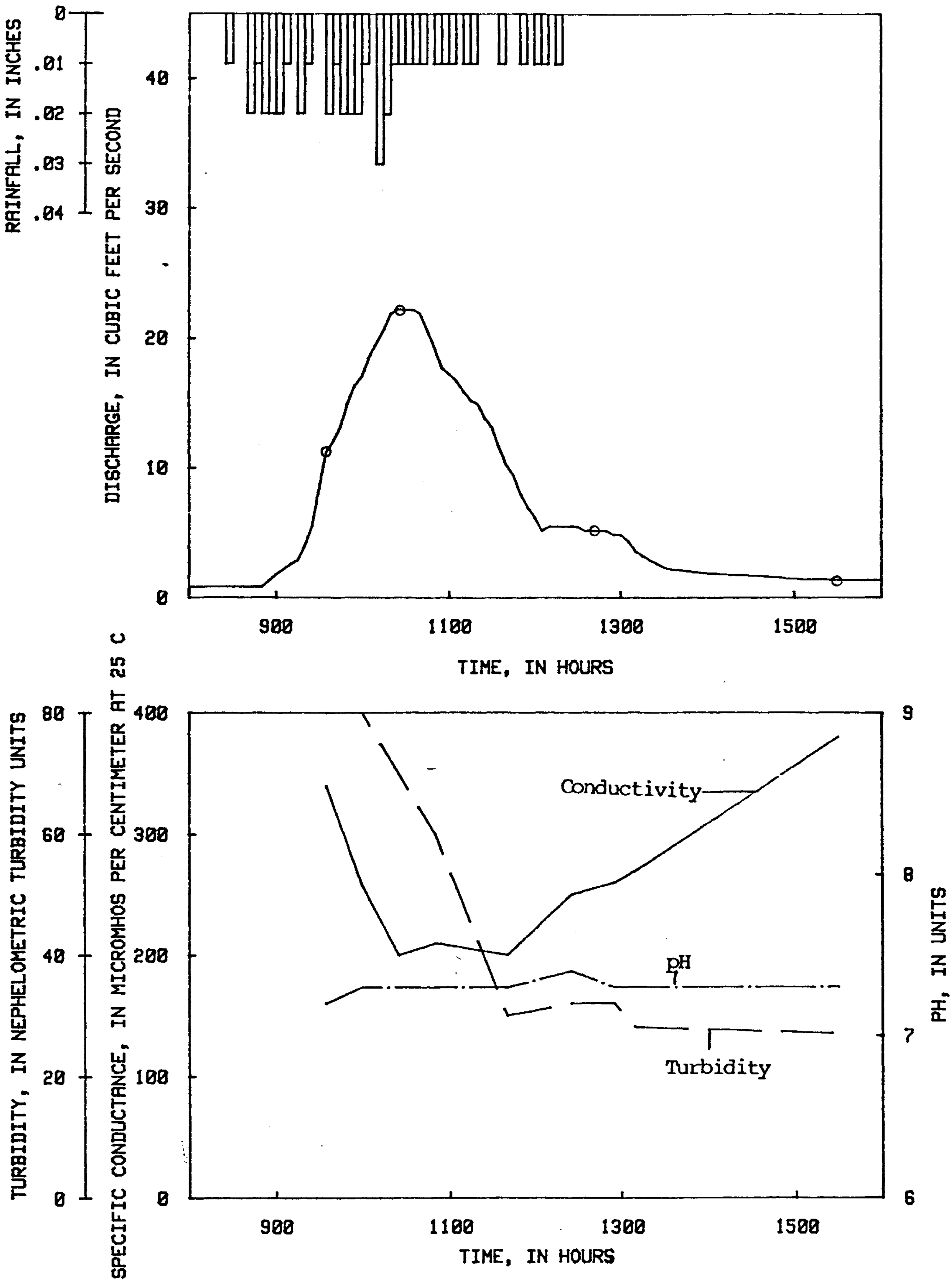



Figure 34.--Rainfall intensity, streamflow, and constituent concentrations for Norman Ditch during storm of April 18, 1978.

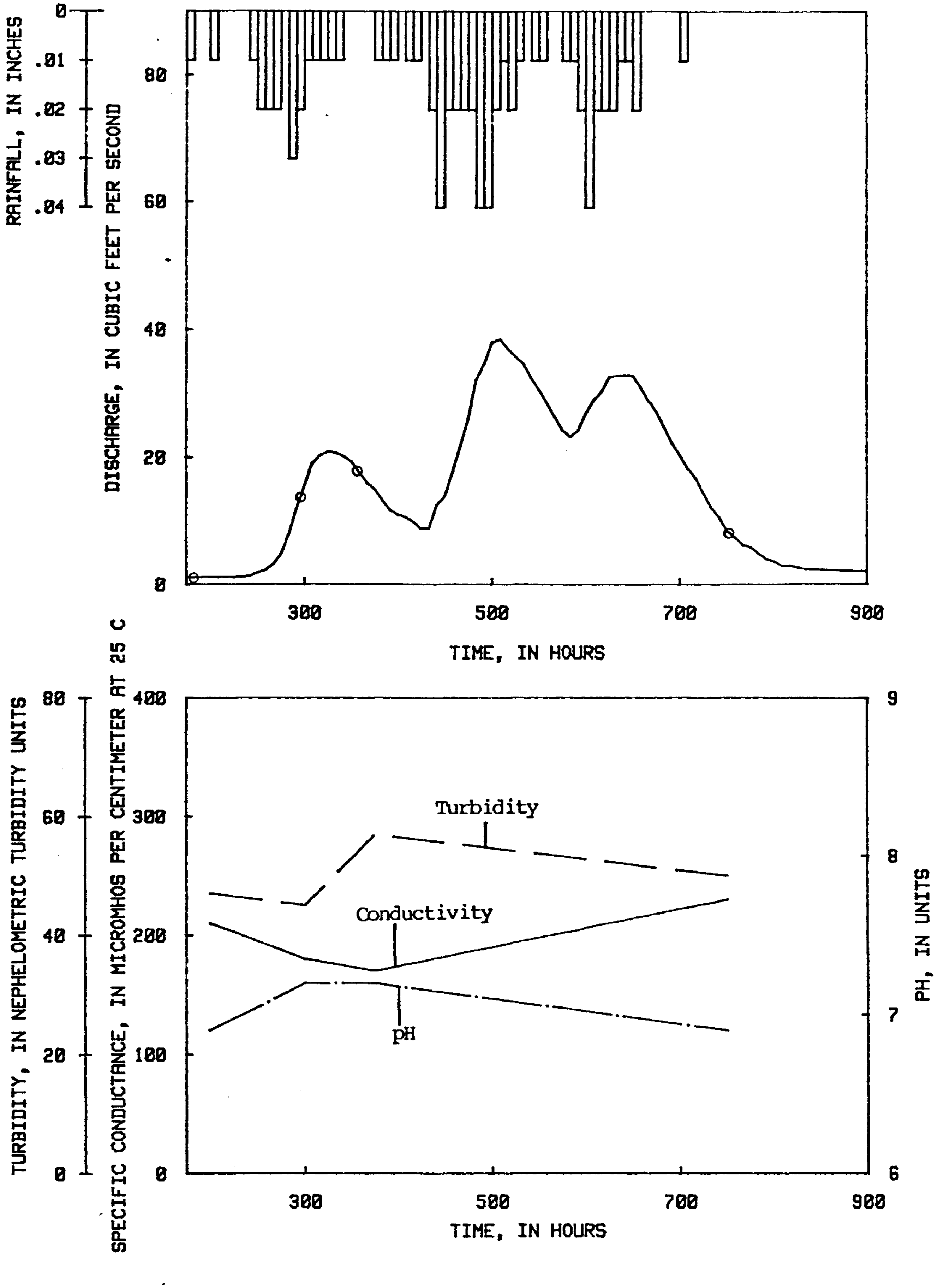
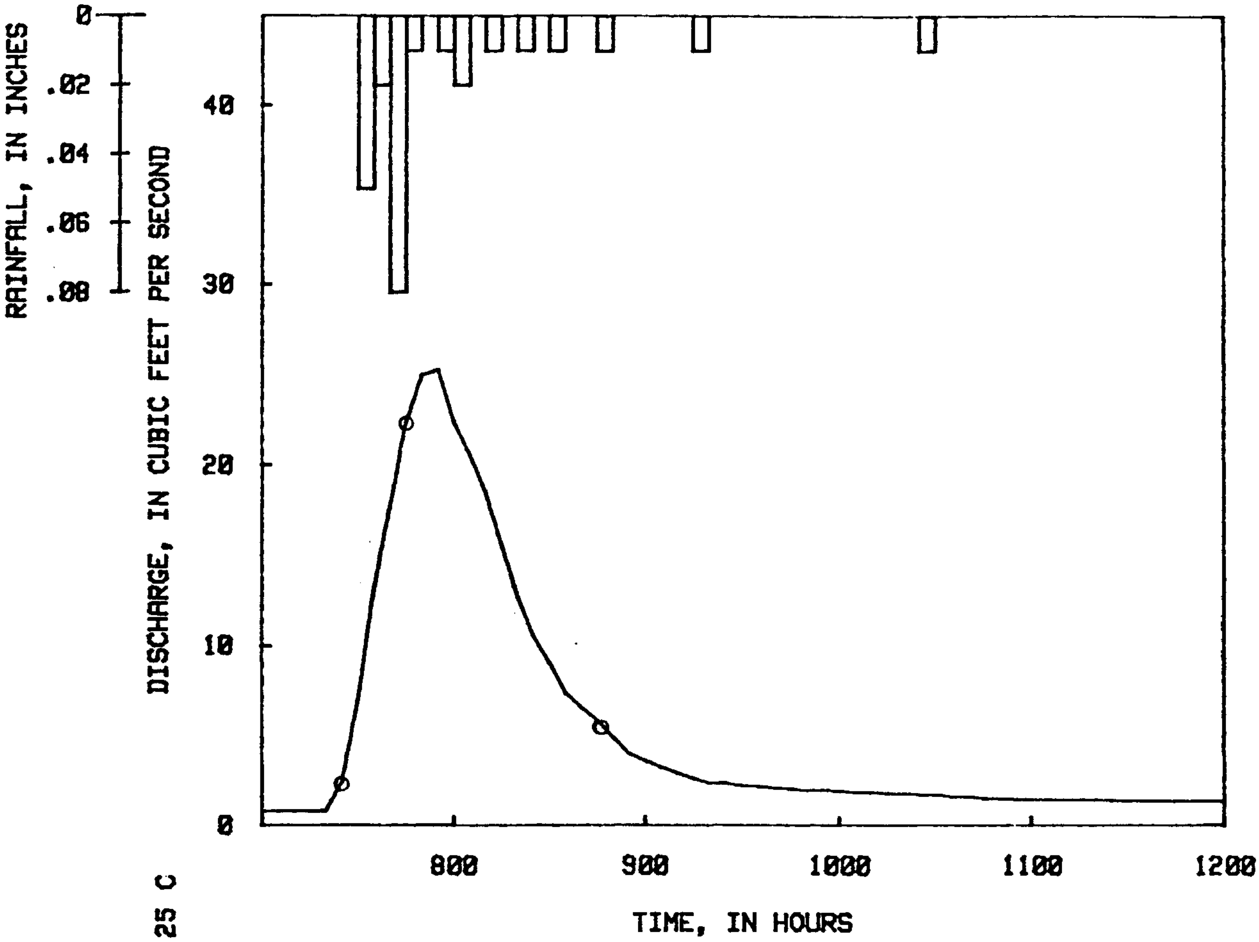



Figure 35.--Rainfall intensity, streamflow, and constituent concentrations for Norman Ditch during storm of May 13, 1978.



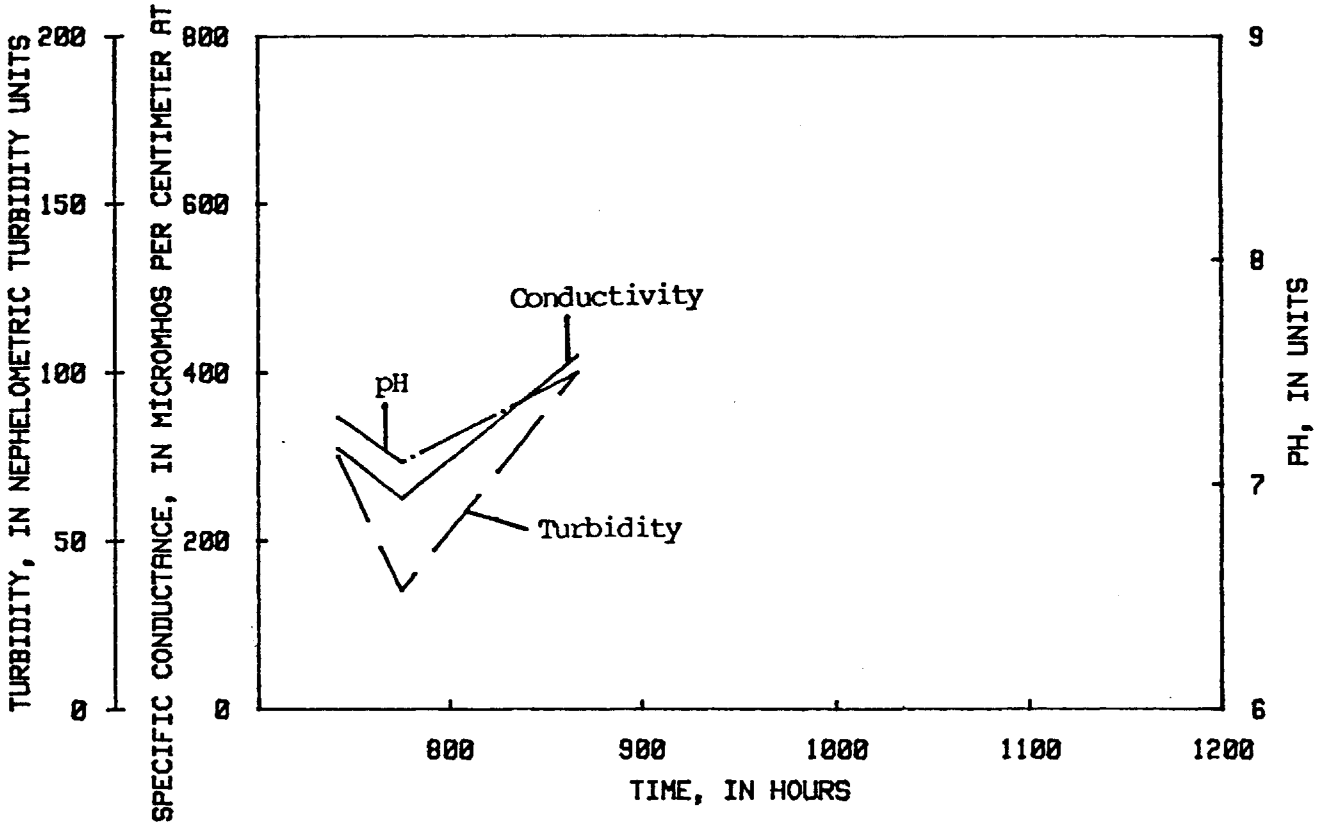




Figure 36 .--Rainfall intensity, streamflow, and constituent concentrations for Norman Ditch during storm of June 7, 1978.

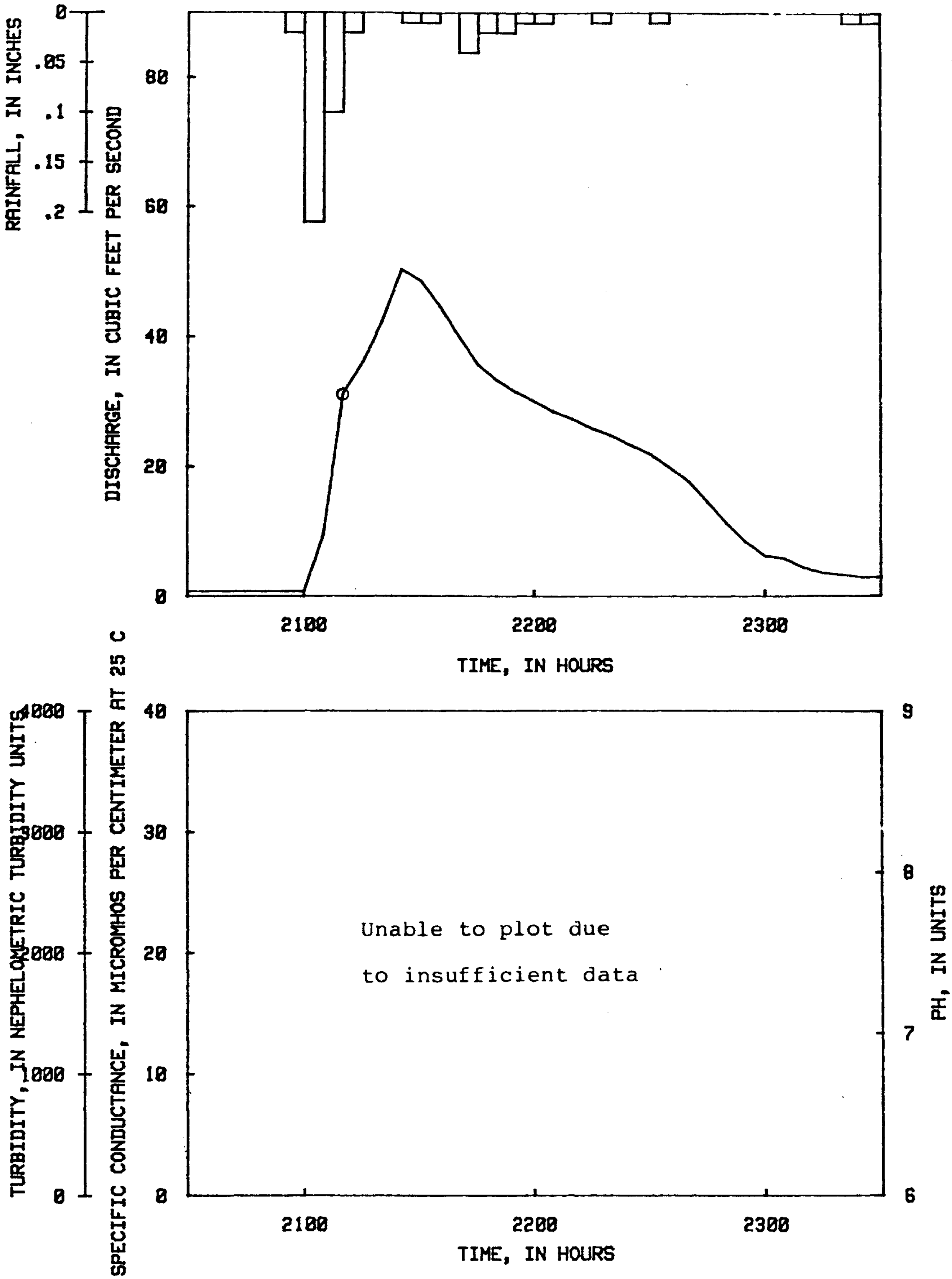
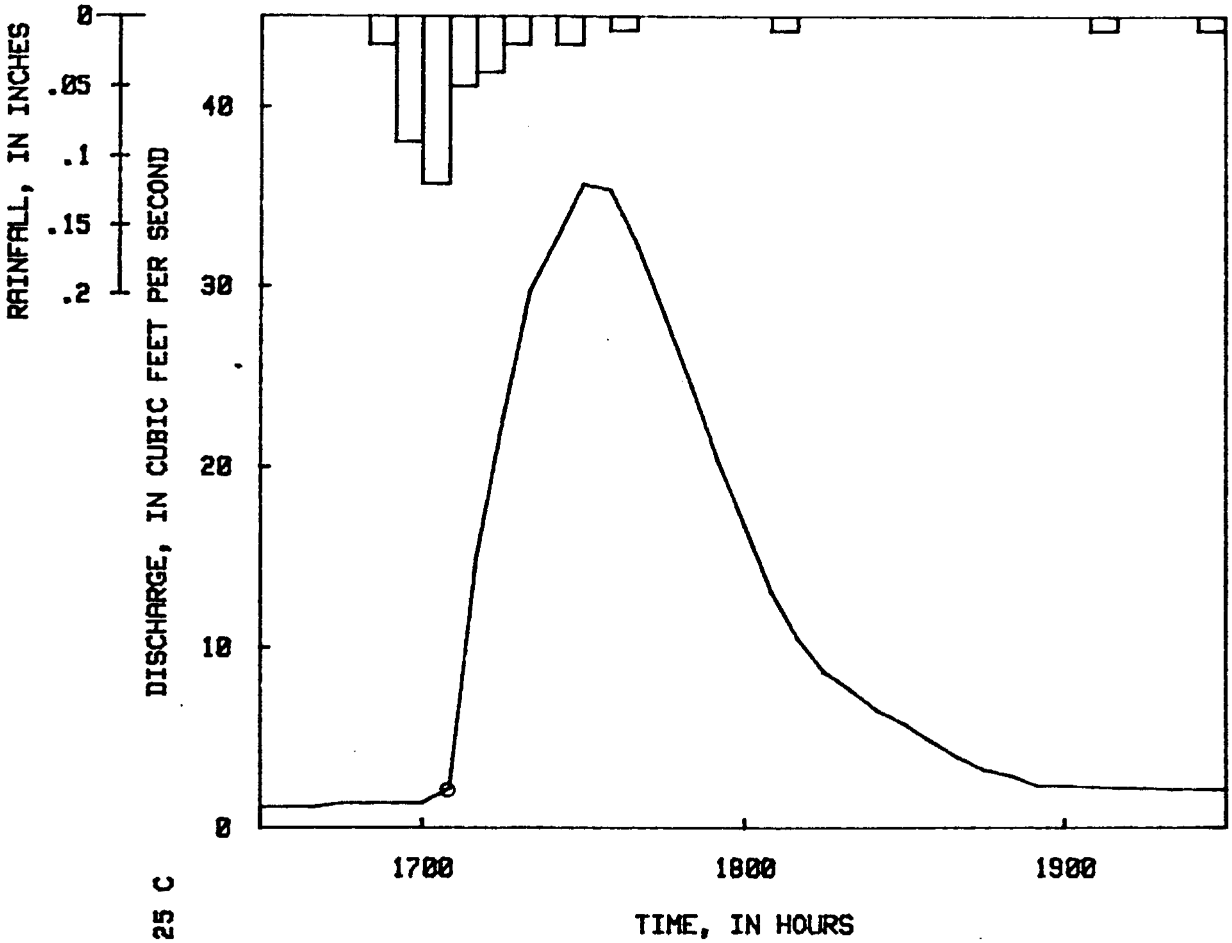



Figure 37.--Rainfall intensity, streamflow, and constituent concentrations for Norman Ditch during storm of June 18, 1978.



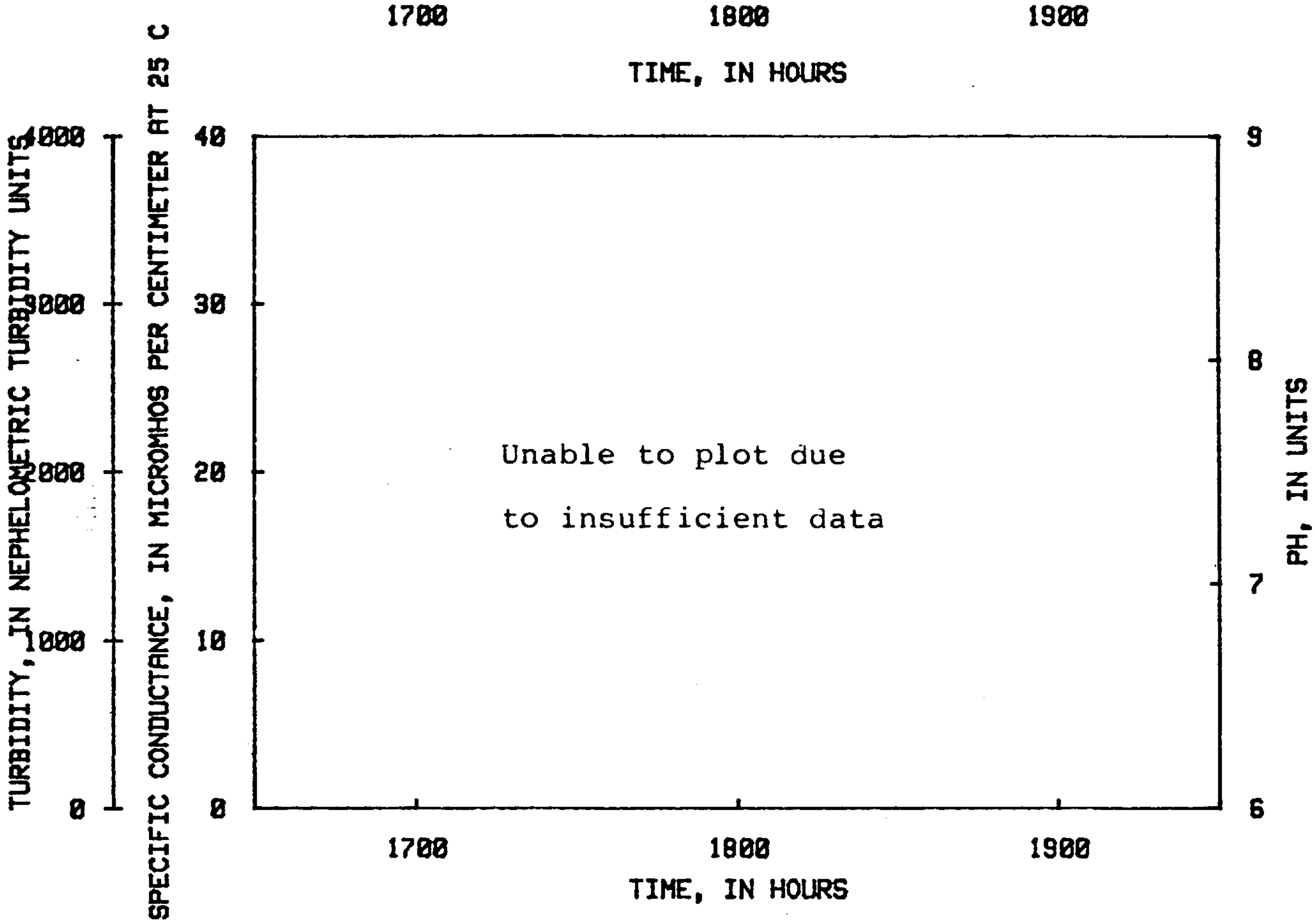




Figure 38.--Rainfall intensity, streamflow, and constituent concentrations for Norman Ditch during storm of July 23, 1978.

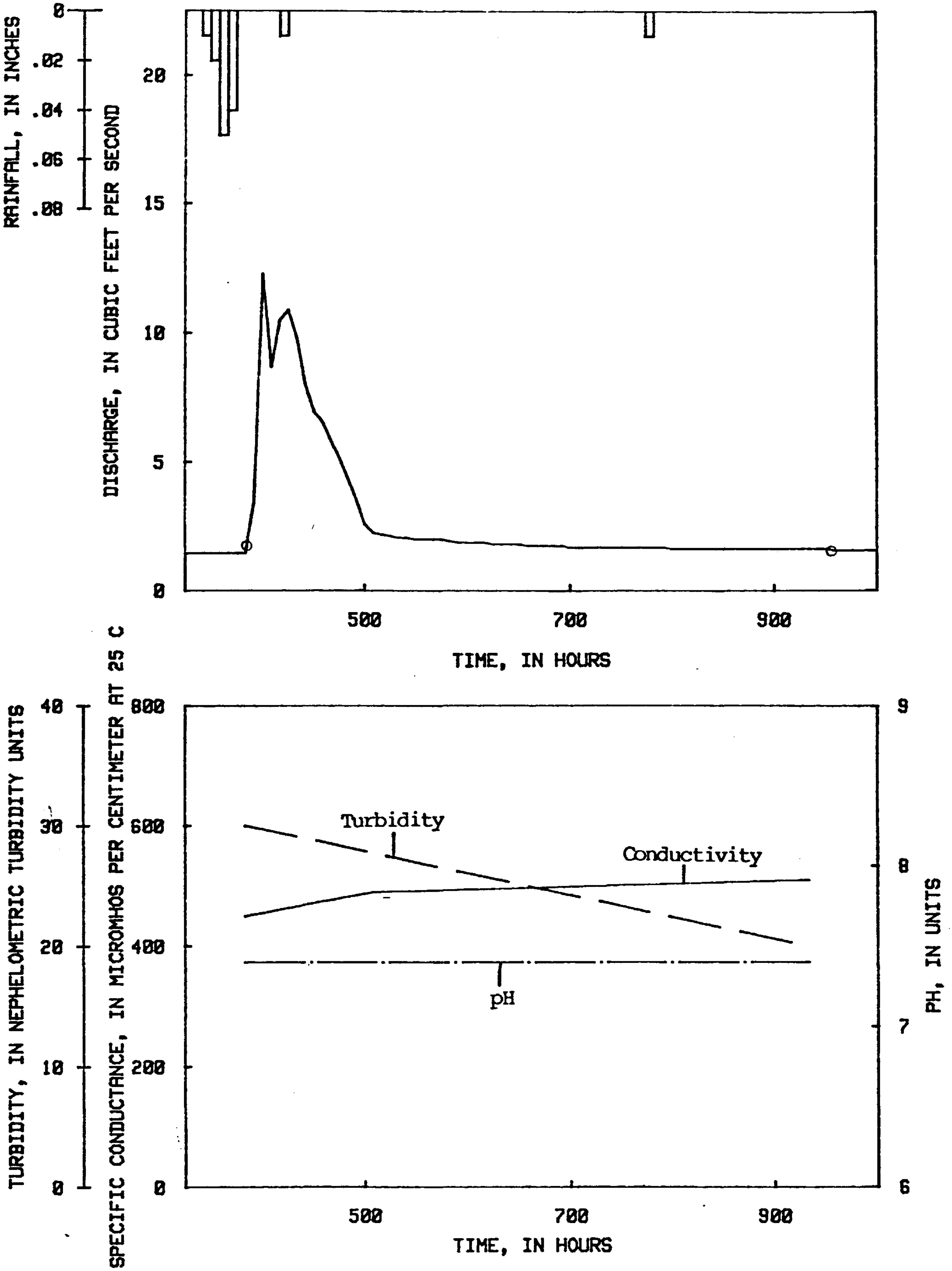



Figure 39.--Rainfall intensity, streamflow, and constituent concentrations for Norman Ditch during storm of August 3, 1978.

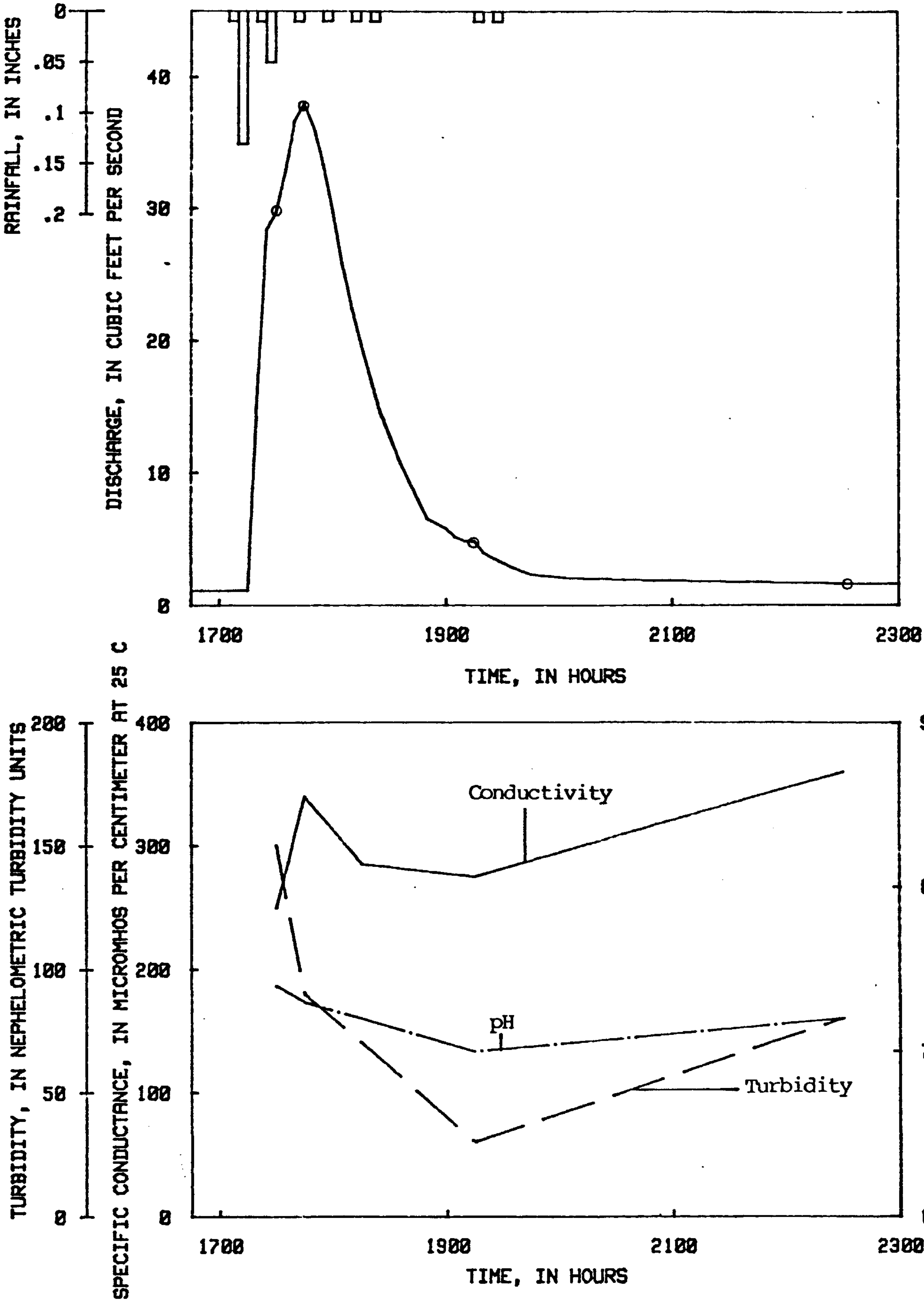



Figure 40.--Rainfall intensity, streamflow, and constituent concentrations for Norman Ditch during storm of August 19, 1978.

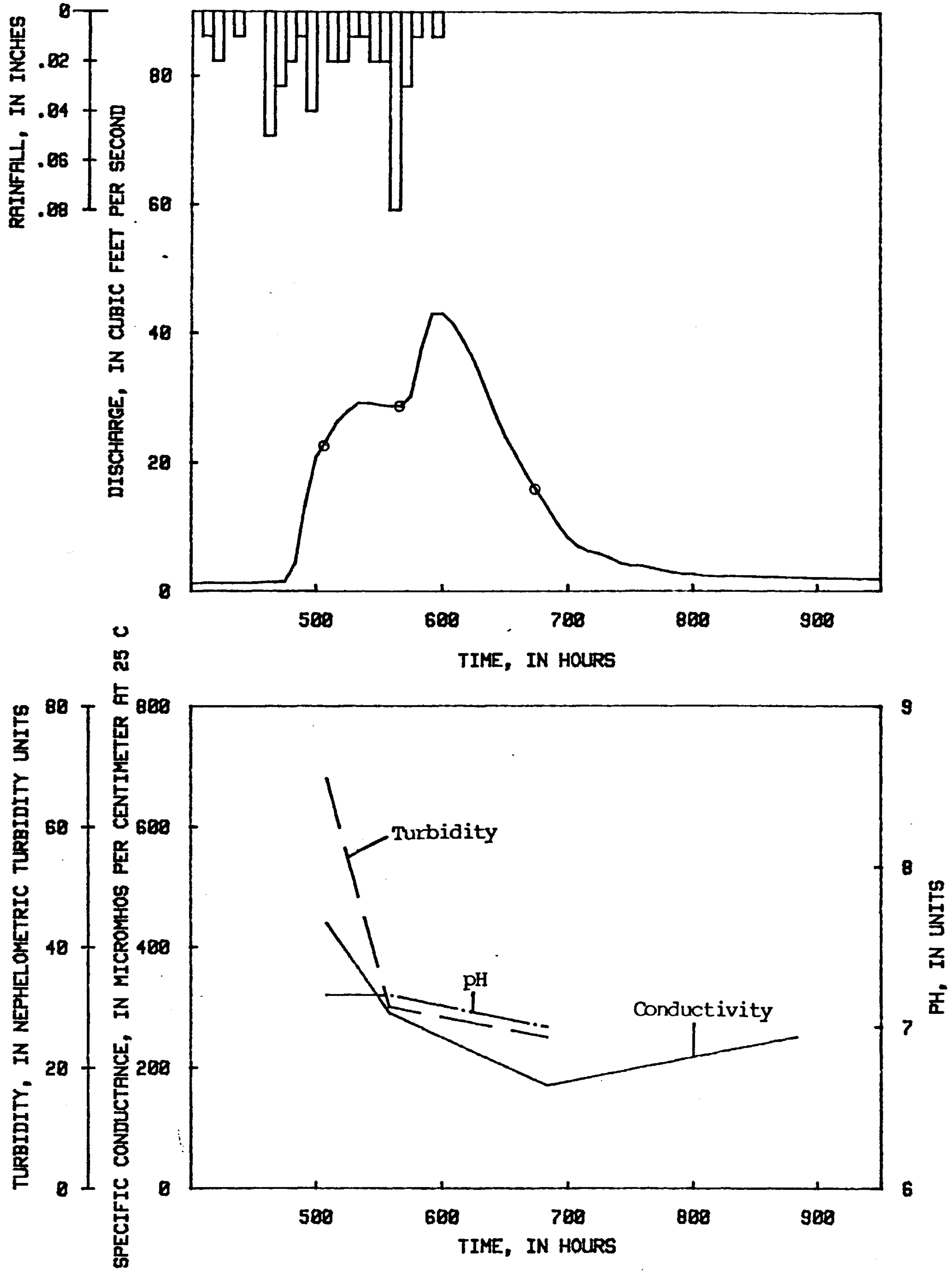
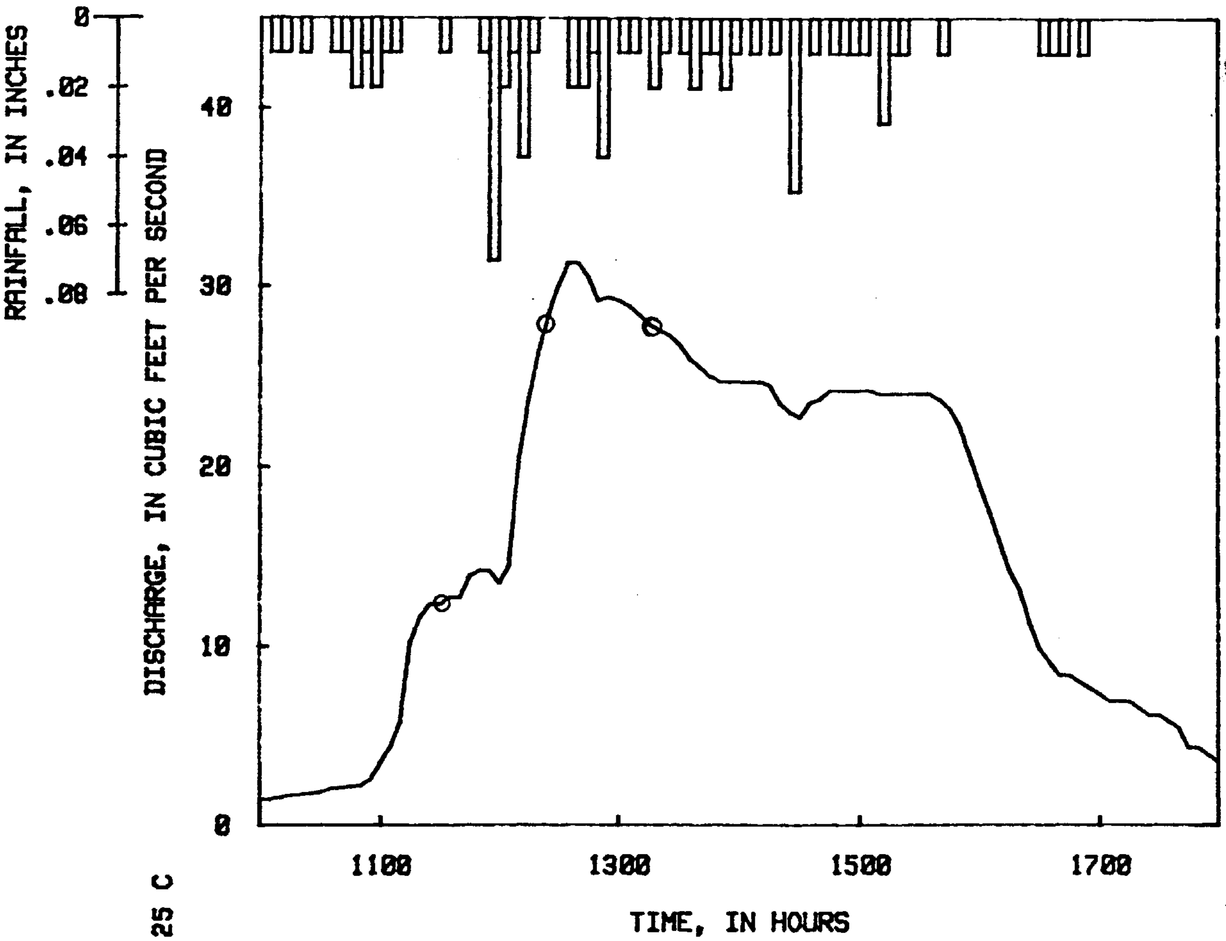



Figure 41.--Rainfall intensity, streamflow, and constituent concentrations for Norman Ditch during storm of August 28, 1978.



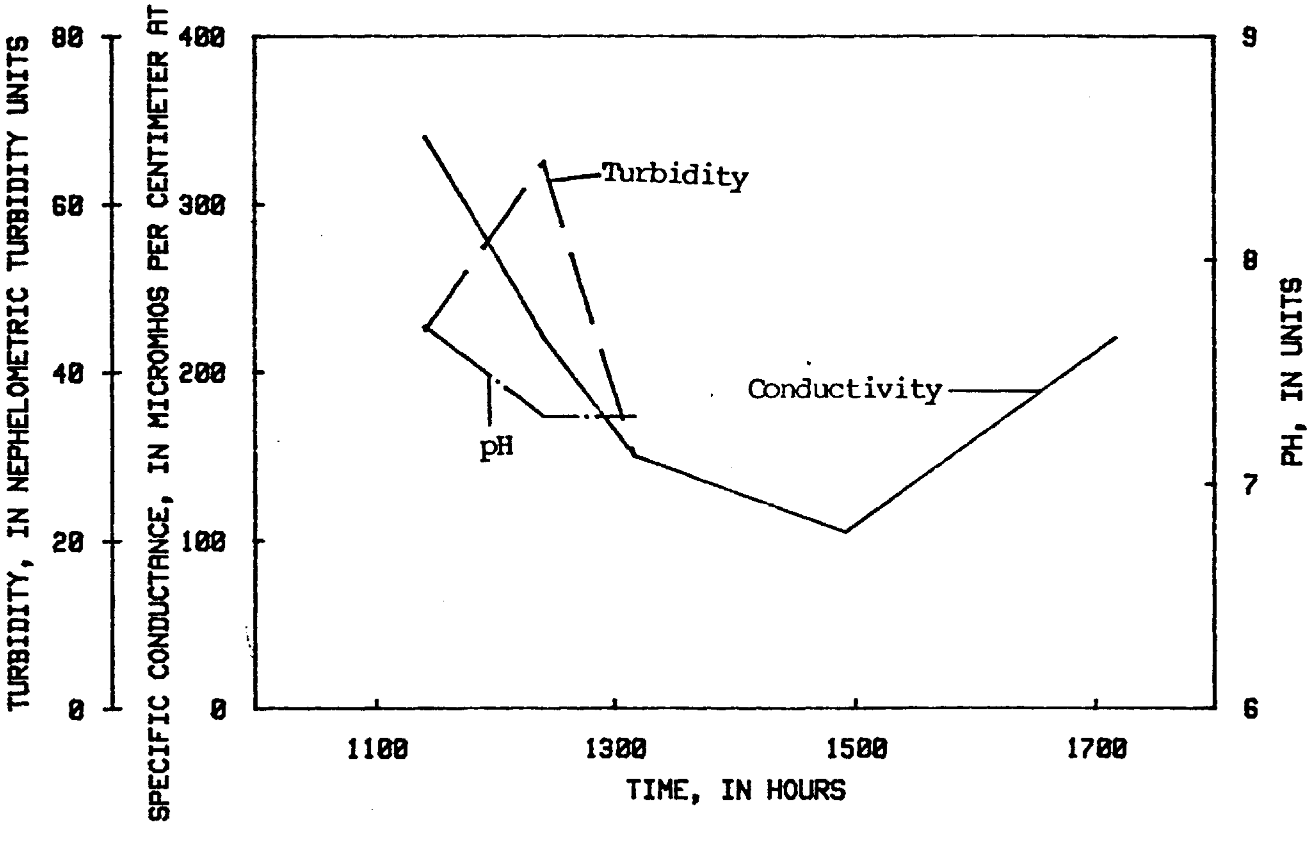




Figure 42.--Rainfall intensity, streamflow, and constituent concentrations for Norman Ditch during storm of August 30, 1978.

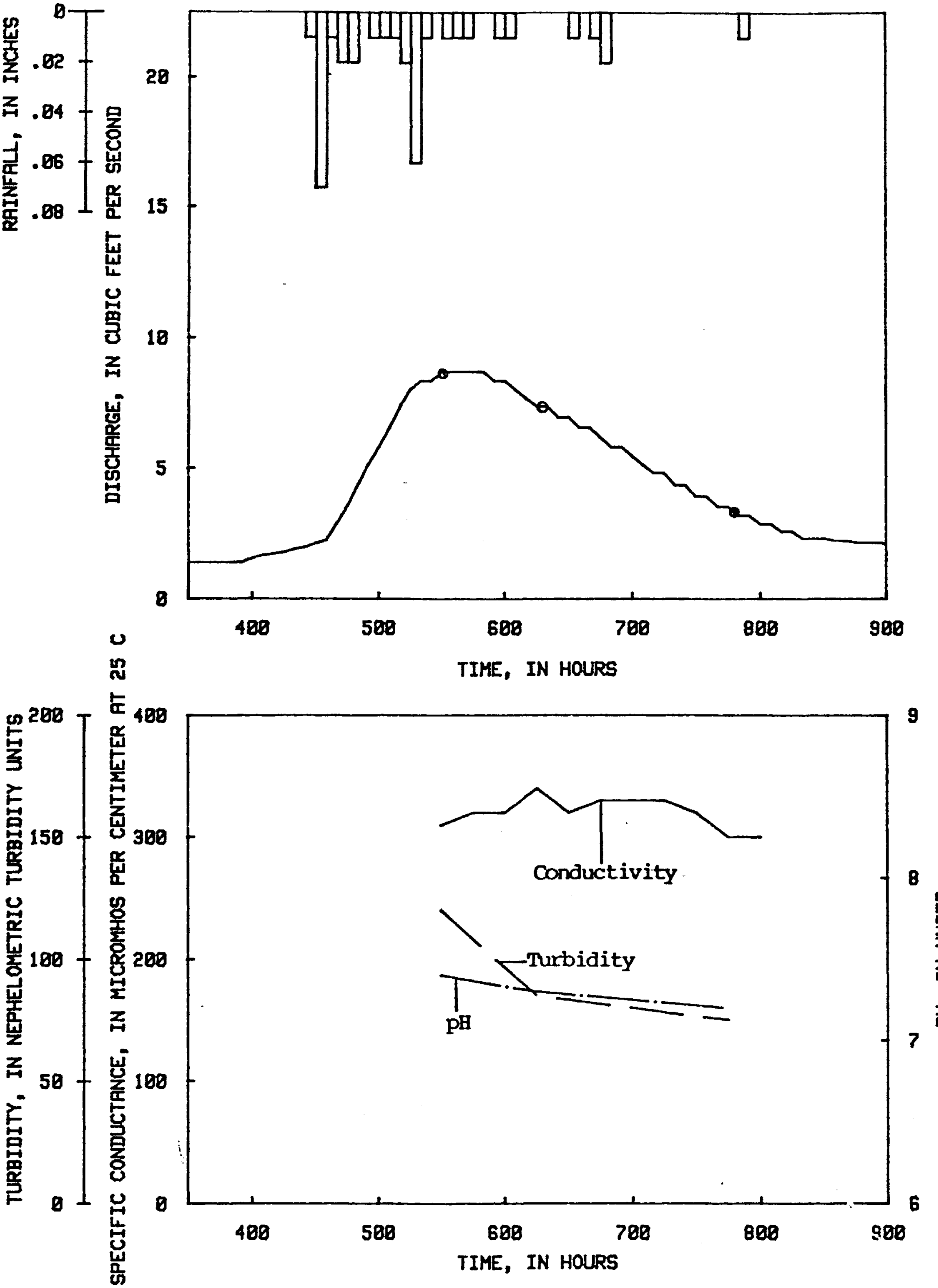
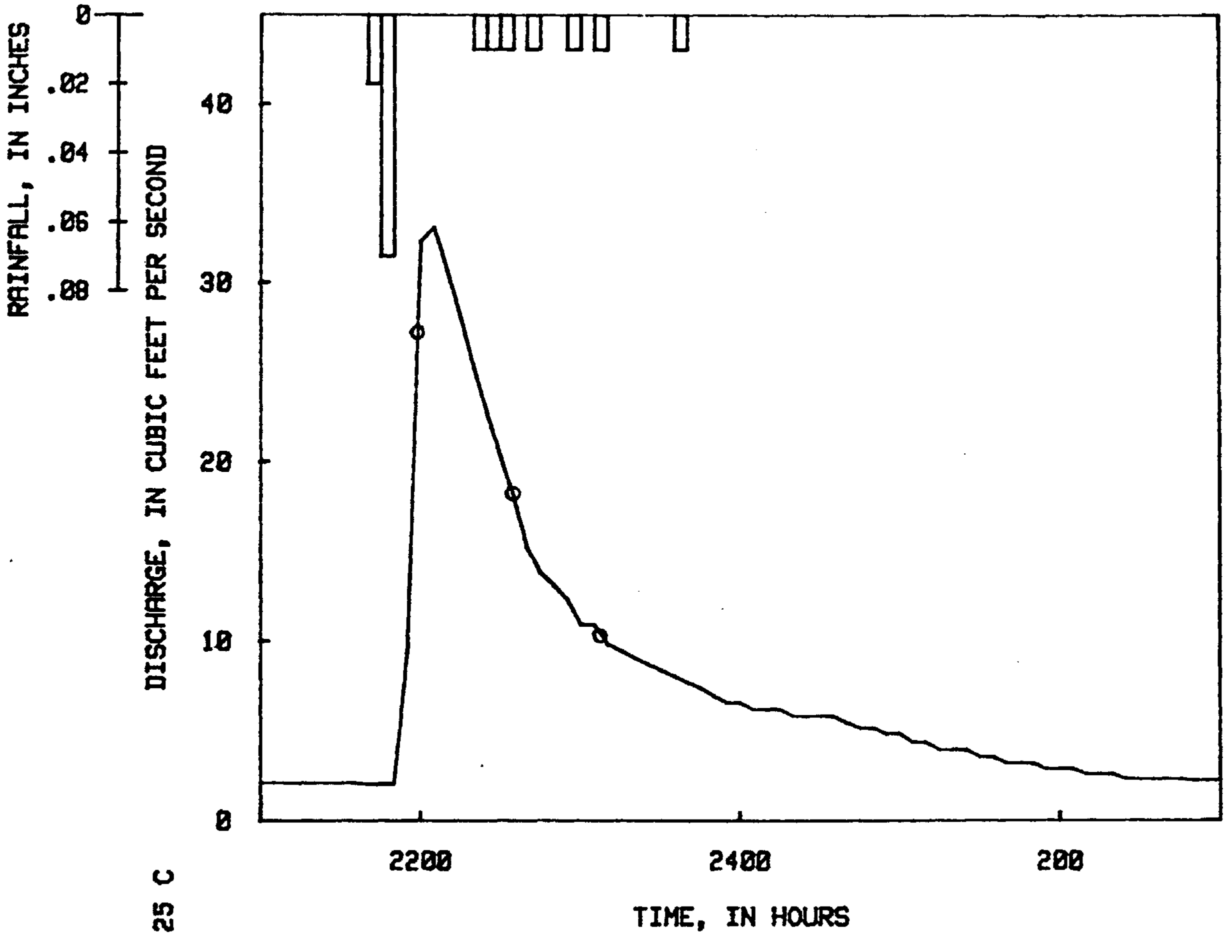



Figure 43.--Rainfall intensity, streamflow, and constituent concentrations for Norman Ditch during storm of March 31, 1979.



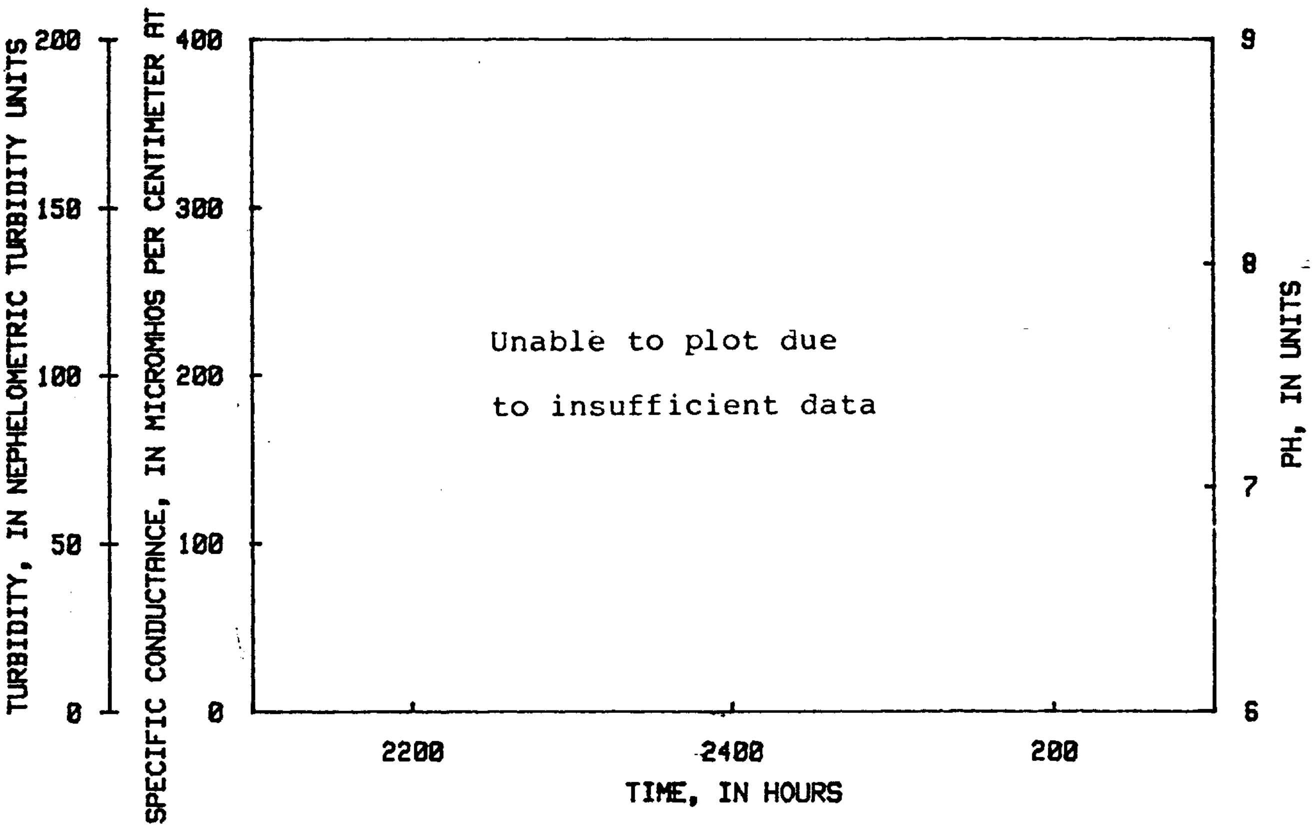




Figure 44.--Rainfall intensity, streamflow, and constituent concentrations for Norman Ditch during storm of July 9, 1979.

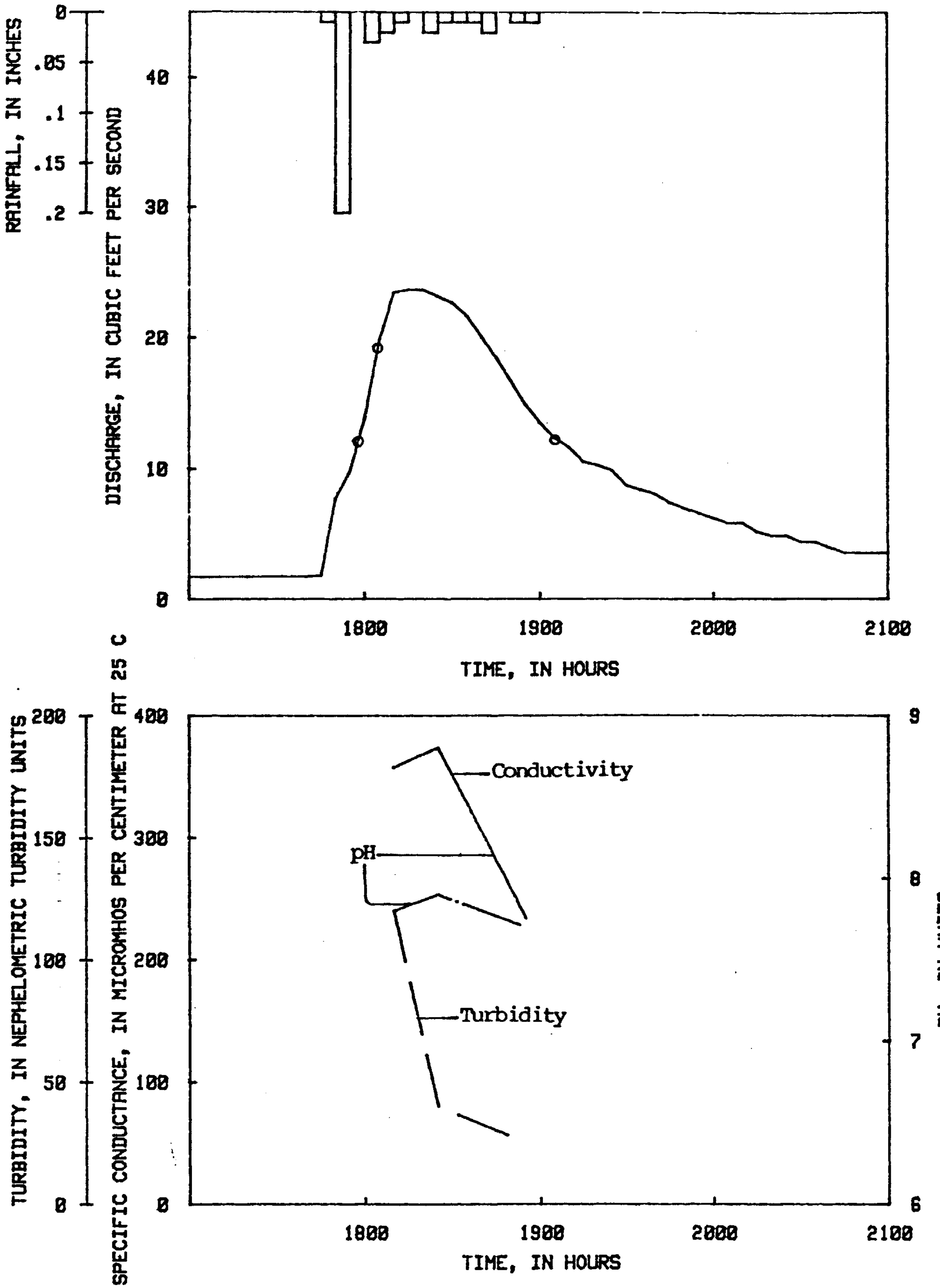



Figure 45 .--Rainfall intensity, streamflow, and constituent concentrations for Norman Ditch during storm of August 1, 1979.

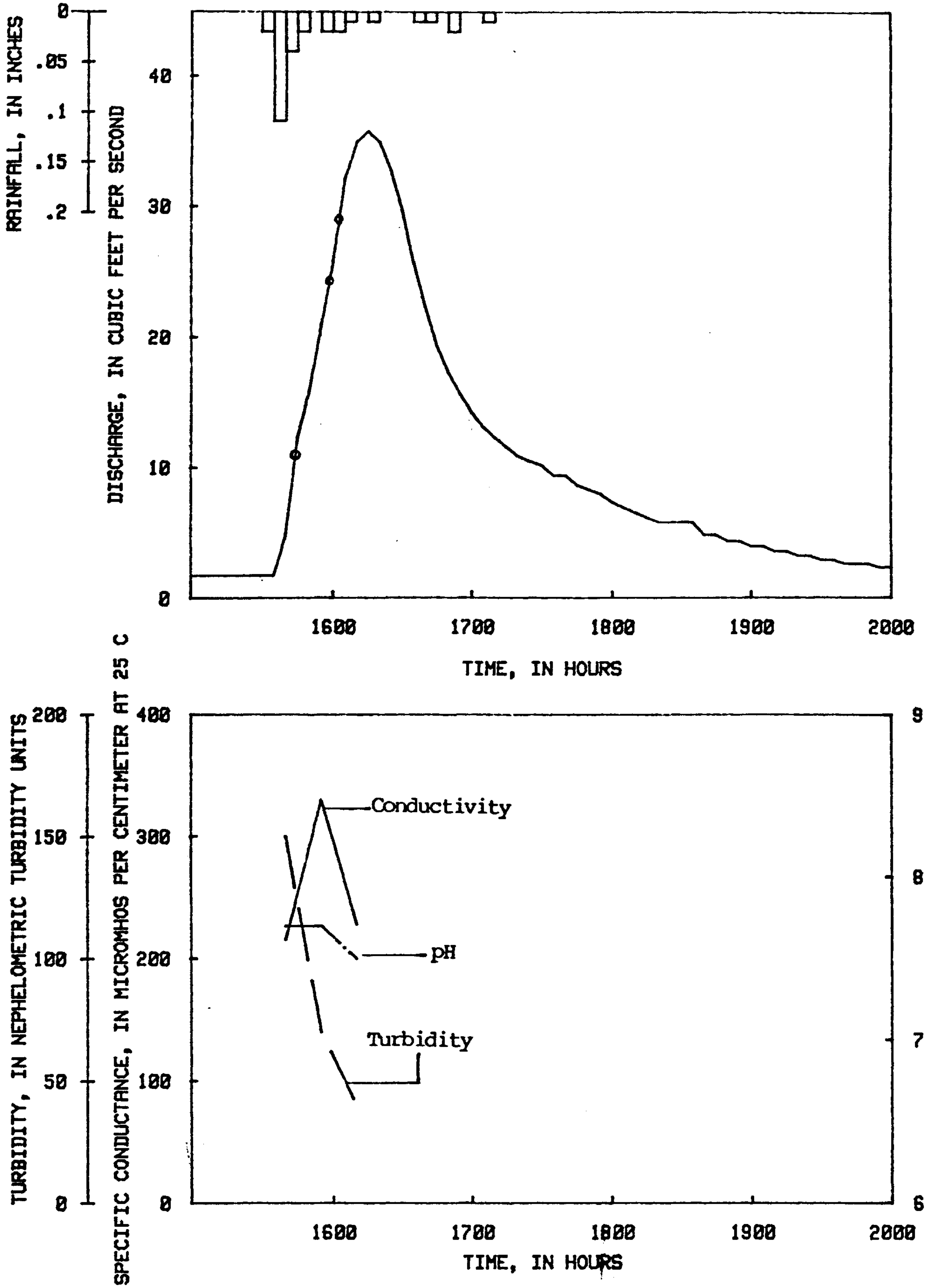



Figure 46.--Rainfall intensity, streamflow, and constituent concentrations for Norman Ditch during storm of August 5, 1979.

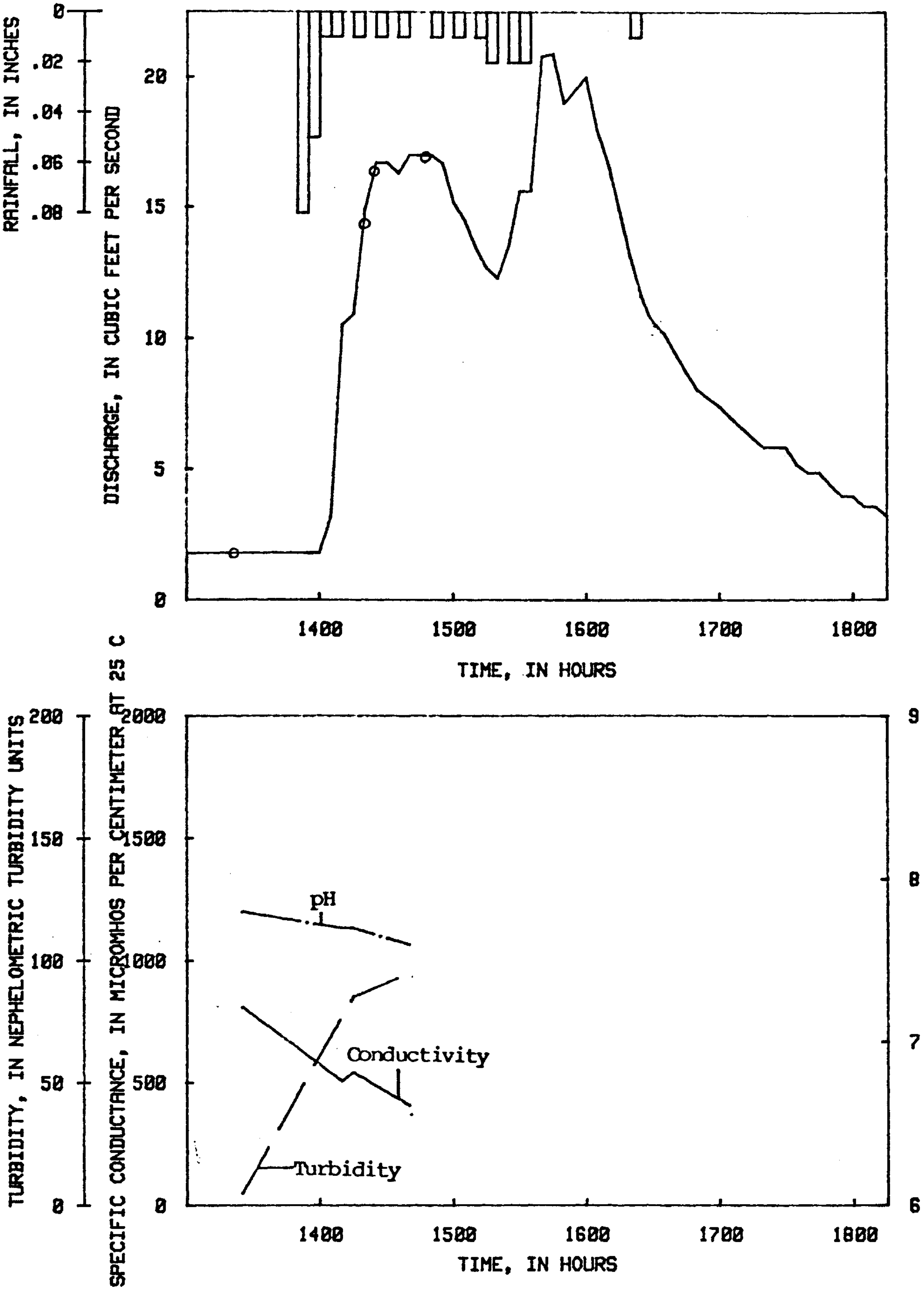



Figure 47.--Rainfall intensity, streamflow, and constituent concentrations for Norman Ditch during storm of August 28, 1979.